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PETROLEUM AND NATURAL GAS IN OKLAHOMA.

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INTRODUCTION.

In the year 1900, the Mid-Continent Field of Kansas and Oklahoma produced 74,714 barrels of oil. In the year 1911, the production was 59,343,850 barrels. The total production for the twelve years 296,614,503 barrels. Of these amounts Oklahoma has produced at least 250,000,000 barrels. The estimated daily production of natural gas in the state is nearly 2,000,000,000 cubic feet. Nine-tenths of all the petroleum and natural gas produced in Oklahoma has come from one of the following nine counties, Nowata, Washington, Rogers, Osage, Pawnee, Tulsa, Creek, Okmulgee and Muskogee, all of which are located in the northeastern part of the state.

While it is still too early to make anything like an accurate prediction as to the future of the oil and gas industry of this state, the time has arrived when a résumé of existing conditions may be made, and perhaps even an intelligent forecast of future possibilities. Enough drilling has been done in many counties of the state to determine with some degree of accuracy not only the formations in which oil and gas are likely to occur, but also the possible amount of these substances yet contained in the ground. While it is true that in matters of this kind prophecy is always unsafe, and the best estimates and the most careful

predictions often go wrong, it may not be amiss at this time to attempt to forecast the future of the industry in Oklahoma.

Practically all the oil and gas so far found in Oklahoma has been obtained in regions occupied by Pennsylvanian, or Coal Measures rocks. Carboniferous rocks occupy all of eastern Oklahoma, except parts, or all, of a half dozen counties east of the Grand River, where rocks of Mississippian age or older occur in the northeastern part of the state, and the counties bordering on Red River in the southern part of the state, where the surface formations are of Cretaceous age.

The Arbuckle and Wichita Mountains, in southern Oklahoma, consist largely of granite and limestone rocks. In these regions no oil or gas may be expected. The western half of the state is occupied by the Red beds; the rocks being of Permian age. In these rocks no oil, or gas, has been found in Oklahoma, except a limited amount in the vicinity of the Wichita and Arbuckle Mountains. In the extreme western part of the state, the Red beds are covered by deposits of Tertiary age. So far as known oil and gas have been found in neither the sub-Pennsylvanian, Cretaceous or Tertiary deposits in Oklahoma.

With these facts in mind it may not be difficult to eliminate certain regions in which the probabilities for finding oil and gas, in paying quantities, are at a minimum. These regions, which will be discussed in very brief detail, include the four mountain uplifts and the greater part of the great Red beds area of western Oklahoma.

THE OZARK UPLIFT.

The northeastern part of Oklahoma is occupied by the southwestern extension of the Ozark uplift, which finds its greatest development in southern Missouri, and in northern Arkansas.

The principal formation of this uplift as exposed in Oklahoma is the Boone Chert, known to the oil driller as the Mississippi Lime. It is a ledge of hard limestone, of Mississippian age, 150 to 350 feet thick, which occupies the crest of the high hills and makes up the plateau lying east of the Grand River. On passing westward this formation dips beneath the surface, and is

overlain by successive deposits of Pennsylvanian or Coal Measures age, from which practically all the oil and gas so far found in the state have been obtained. A number of wells have been drilled through this Boone Chert, but so far as known neither oil nor gas, in paying quantities, has been found beneath this formation.

Exposures of the Boone Chert occur in Ottawa, Delaware, eastern Mayes, Cherokee, Adair, northern Sequoyah, and eastern Muskogee counties. Judging both from geological conditions and practical experience, it is practically useless to attempt to find oil or gas in this region.

THE OUACHITA MOUNTAINS.

The Ouachita Mountains occupy an area of several thousand square miles in the southeastern part of the state, extending from central Atoka County east to the Arkansas line. Included in this area is eastern Atoka, southern Pittsburg, southern Latimer and southern LeFlore counties, northern McCurtain and practically all of Pushmataha counties.

The rocks of the Ouachita Mountains consist of alternating strata of sandstones and shales, probably of Carboniferous age, which have been greatly faulted and folded, so that, at the present time, the rocks are standing practically on edge. The various heavy sandstone members form long timber-covered ridges. The thick deposits of shale have been worn into narrow valleys.

There are in these mountains considerable deposits of asphalt, usually in the form of grahamite and gilsonite. These deposits are found intruded in crevices among the shales, or between bedding planes. It is quite probable that these asphalt deposits represent the residuum of petroleum which existed in former geological ages, from which the volatile lighter oils and gases have been distilled. If this assumption be true, it is practically useless to attempt to find oil or gas in paying quantities in the Ouachita Mountains.

THE ARBUCKLE MOUNTAINS.

These mountains are located in the southern part of the state, occupying southern Pontotoc, western Coal, northern Johnson, southern Murray, and northeastern Carter counties. The mountains consist of an uplifted, truncated dome, with a granite core, along which are flanked sandstones, limestones, and shales of lower Paleozoic age. These rocks have been greatly faulted and folded in the process of uplifting. Many deposits of asphalt, both in the pure state, and as impregnations of sedimentary rocks, occur in, or near, the Arbuckle Mountains. It appears very probable that the conditions which lead to the formation of asphalt must have eliminated the more volatile hydro-carbons, and for this reason it is apparently useless to attempt to find petroleum, or natural gas, in quantity in the Arbuckle Mountains.

THE WICHITA MOUNTAINS.

The Wichita Mountains, in southwestern Oklahoma, are structurally very similar to the Arbuckle Mountains, consisting of an uplifted, truncated dome flanked by lower Paleozoic sediments. In the case of the Wichitas, however, erosion has progressed to a much greater extent than in the Arbuckle Mountains, so that the Wichita Mountains consist very largely of jagged peaks of red granite. The Paleozoic limestones are relatively inconspicuous. Deposits of asphalt occur in the limestones, and in the Red beds shales and sandstones, near the edge of the mountain uplift, and small quantities of oil and gas have been found at no great distance from the mountains. These will be discussed later.

THE RED BEDS AREA.

As stated above, the western part of Oklahoma is occupied almost exclusively by the Red beds, the term being used in a general sense to describe a vast deposit of rocks of Permian age, the prevailing color of which is a deep brick-red. The rocks consist largely of red clay shales with occasional interbedded ledges of some other rock, usually either soft sandstone, massive white gypsum, or rather thin ledges of dolomite.

Until the last few years, it was believed by practically all geologists who had studied the problem, that the chances for finding oil or gas in quantities anywhere in the Red beds area were very meager. A few unimportant oil and gas wells near Lawton, Granite, and Gotebo, in the vicinity of the Wichita Mountains, and a few shallow water wells containing small amounts of oil and gas, which have been drilled in the region southwest of the Arbuckle Mountains, in what is now Carter, Stephens, and Jefferson counties, demonstrated, however, that oil and gas actually did occur in these rocks. The finding of small amounts of these substances lead to the hope that continued drilling throughout the region might reveal the presence of considerable volumes of these hydro-carbons.

Within the past five years, three very prolific oil fields have been found in the Red beds. These are the Wheeler Field, in Carter County, Oklahoma, less than ten miles from the Arbuckle Mountains; the Petrolia Field, in northern Clay County, Texas; and the Electra Field, in Wichita County, Texas. The Petrolia and Electra Fields are about ten miles south of the Red River. It is a very significant fact that all the oil and gas so far found in the Red beds occur at a distance less than fifty miles from a mountain range. In all of these fields, however, while the surface rocks are the ordinary Red beds, the oil and gas are encountered in ledges of sandstone either near the base of these Red beds, or in and among the non-red sediments beneath.

These facts have compelled both the geologist, and the theoretical oil man, to revise his statements, and have materially extended the probable areas within which oil and gas may be profitably sought.

There is still, however, a very large area in central, western, and northwestern Oklahoma, within which there is slight chance of finding oil and gas. This is the great area of Red beds rocks, which, so far as is known, contain few, or no, ledges of sandstone capable of storing quantities of oil or gas, and which were laid down at a considerable distance from any known mountain range.

Taking these facts into consideration, it may be possible to

eliminate a number of counties from the area of the probable future oil fields of the state. These will include the three Panhandle counties in northwestern Oklahoma, namely: Cimmaron, Texas, and Beaver counties, as well as Harper, Woods, Alfalfa, Ellis, Woodward, Major, Roger Mills, Dewey, Custer, Blaine, Kingfisher, and Canadian. To these should, in all probability, be added, Grant, Garfield, Logan, Oklahoma, Cleveland, McClain, Grady, Caddo, Washita, and Beckham counties. That is to say, in the light of our present knowledge, taking into account the stratigraphy, structure of the rocks, the conditions under which they were laid down, the known absence of large beds of sand capable of storing petroleum, and all other known data, the chances for finding oil, or gas, in paying quantities, in these regions are extremely small. It is, however, within the limits of possibility that continued drilling will reveal the presence of small deposits of both oil and gas in some of these counties, particularly in eastern Grant, Garfield, Logan, Cleveland, and McClain, and in southern Grady, Caddo, Washita, and Beckham Counties; but chances for finding them in paying quantities are so meager that it would not seem wise to recommend the investment of money in drilling operations. At least half a million dollars have been spent within the past ten years in holes in the ground in western Oklahoma, and not a dollar has ever been returned, nor does there seem to be any likelihood of anything of value being found in this region.

There are, however, in southwestern Oklahoma within the area occupied by the Red beds some eleven counties, in which the chances for finding oil and gas in paying quantities are as good as in the Wheeler, Petrolia, or Electra Fields. For if the assumption be true that the oil and gas found in these fields already developed has been stored in sandstone ledges, which in a former geological age were an out-wash from the Arbuckle or Wichita Mountains, it must be admitted that other localities, in the same part of the state, have equally good chances for containing these prolific sandstones. The counties included in this area which may be considered good prospective oil and gas territory are

Harmon, Greer, Jackson, Kiowa, Tillman, Comanche, Stephens, Jefferson, Carter, Garvin and Love. Within the area occupied by these eleven counties are included all of the Wichita Mountains, as well as the western end of the Arbuckle Mountains. While it is probably true that large amounts of money will be spent in drilling in impossible places, in these counties, the chances are that continued drilling in favored localities will reveal the presence of several oil fields of considerable size.

CRETACEOUS AREA.

The counties occupied by Cretaceous rocks along Red River, in the southeastern part of the state, are an unsolved problem. The surface formations in these counties consisting of sandstones, shales and limestones, were, during Cretaceous times, spread out, blanket-like, over what appears to be the upturned ledges of Pennsylvanian, or Coal Measure rocks. Oil has been found in small quantities, presumably near the base of the Cretaceous rocks (the top of the Pennsylvanian) at Madill, Hugo, and other points in the area, and it is altogether possible that extensive drilling throughout the Red River counties may encounter considerable deposits of oil. There is, however, in this region no geological evidence, either positive or negative, on the surface, that would enable one to locate a prospective oil field.

DEVELOPED FIELDS.

Having eliminated the apparently impossible regions, and discussed in some detail those parts of the state in which the chances for finding oil are only fairly good, let us now turn our attention to the great Pennsylvanian area, in eastern Oklahoma, which has heretofore been the great producer of petroleum. By far the greater part of the oil and gas so far produced in Oklahoma have come from nine of the northern and eastern counties. There are some twenty other counties, which lie either within the known field, or along its edges, or are occupied by rocks of Pennsylvanian age, all of which should, in all probability, produce considerable quantities of oil or gas. These counties will be dis-

cussed in brief detail. Many of the statements made, however, must be accepted tentatively, for it must be remembered that new developments are constantly extending the known areas of the possible fields, and that regions, which a year ago would have been considered worthless, are now considered good prospective territory. On the other hand, the finding of "dry holes" in regions considered good will often condemn a considerable area.

Washington County.—Some of the first wells drilled in Oklahoma were located near Bartlesville, in this county. The greater part of the county has proved productive of oil or gas, and practically all of the northern half has been drilled. Some of the most prolific oil pools in Washington County are the Ramsey, Canary, Cotton Creek, Copan, Wann, Webber, Dewey, Squirrel, Bartlesville, Oglesby, and Ramona oil pools as well as the world-famous Hogshooter Gas Field. Many million barrels of oil have been taken from this county, and it is very probable that only a relatively small part of the oil has yet been exhausted. There are three known productive sands, none of them over 1,400 feet in depth.

Nowata County.—This county includes the greater part of the famous Shallow Field of Oklahoma. The territory east of the Verdigris River, in the southeastern part of the county, is practically all producing territory. Some of the most noted pools are the Alluwe, Coodys Bluff, Big Creek, Childers, Delaware, Delaware Extension, Lenapah, Berea, and Adair. Considerable areas in the northern and western parts of the county remain to be drilled. This has proved a very profitable county in which to operate, because of the fact that the wells are all shallow. In the Alluwe Field, for instance, the oil is found at a depth of not more than 500 feet.

Rogers County.—This county also lies within the Shallow Field. The Chelsea pool in the northeastern part of the county; the Sageyah pool near Claremore, and the Collinsville gas field in the western part of the county, are, at the present, the most prolific areas so far discovered. Oil has been found, however, near Inola, Catoosa, Talala, Oologah, and other points. A large part of the county, however, remains to be drilled.

Tulsa County.—Tulsa County includes such pools as Skiatook, Bird Creek, Flat Rock, Perryman, Red Fork, and the eastern half of the world-famous Glenn Pool, which within the past five years has produced over 100,000,000 barrels of oil. A large part of the county has not yet been drilled, and it is quite probable that a number of additional pools will yet be located.

Osage County.—Only a small part of the eastern half of Osage County has been prospected, owing to government restrictions upon the leasing of land. Practically all of the territory drilled has been found to be prolific of oil and gas. Wells are located along the eastern line of the county all the way from Kansas to the Arkansas River. Some of the most noted pools in Osage County are at or near Bartlesville, Bighart, Osage, and Skiatook. Western Osage County, which should be prolific of oil and gas, has not been drilled. It is probable that hundreds of millions of barrels of petroleum will yet be produced from this county.

Pawnee County.—Pawnee County includes the noted Cleveland Field, which was one of the first developed in the state. There are in the Cleveland Field five producing oil sands, located at depths ranging from 1,000 feet to 2,700 feet. The largest well ever discovered in the state was found in this field. It produced 7,000 barrels of oil per day, and was located in the Bartlesvilles and, at a depth of 2,700 feet. Practically all of the southern and western parts of Pawnee County remain to be drilled, and it is very probable that many additional oil pools will be found.

Creek County.—The western part of the Glenn Pool, the largest field in Oklahoma, and its northern extension, the Tamaha Pool, are both located in eastern Creek County. Forty miles away in the western part of the county is the newly discovered Cushing Pool, which bids fair to rival the Glenn Pool. All of the intervening country, as well as several hundred square miles in the southern part of the county, remains to be drilled. It need occasion no surprise if this county eventually produces hundreds of millions of barrels of oil.

Okmulgee County.—There are a number of producing oil pools in Okmulgee County; the most prolific of which are the Okmul-

gee, Hamilton, Beggs, Baldhill, Morris, Tiger Flats, Henryetta, and Salt Creek Pools. Large areas known to be productive of oil and gas have not yet been drilled.

Muskogee County.—In Muskogee County is located the noted Muskogee oil pool, also producing pools near Haskell, Wainwright, and Council Hill. Considerable part of southern Muskogee County has not yet been drilled.

Wagoner County.—Oil and gas have been found in Wagoner County, near Choska, Coweta, and along Adams Creek, east of Broken Arrow. Practically all the county is good prospective oil territory, but very little of it has been drilled.

Mayes County.—A small amount of oil and gas has been found in the western part of Mayes County, in the region west and north of Pryor Creek. All that section of the county lying west of the main line of the Missouri, Kansas, and Texas Railroad is a part of the territory within which oil and gas may be found, and if found, drilling will be inexpensive on account of the fact that the wells will not exceed 300 to 500 feet in depth.

Craig County.—Western Craig County lies within the territory in which oil and gas may be expected. The drilling will not be expensive because of the shallow depth of the wells. Oil and gas have been found near Catale and Centralia.

Kay County.—The principal oil pool so far developed in Kay County is the Ponca City pool, which, during the last year, has produced a large amount of oil and gas. Both oil and gas are known to occur near Kildare and Newkirk, also large amounts of gas in the western part of the county, near Blackwell. There need be no surprise if extensive drilling anywhere in Kay County reveals the presence of oil and gas.

Noble County.—Western Noble County lies in the Red beds and for that reason the chances for finding oil and gas are not so good as in eastern townships, which, when drilled, should show considerable amounts of these products.

Payne County.—Eastern Payne County doubtless contains oil and gas. The famous Cushing Field, in Creek County, lies just across the line, and the northeast corner of the county is but a

few miles from Cleveland, one of the most prolific fields in the state. Western Payne County lies within the region of the Red beds, where the chances for finding these substances are not so good.

Lincoln County.—Eastern Lincoln County is fairly good prospective oil and gas territory. Western Lincoln County lies in the Red beds area. The chances are not good for finding oil and gas in paying quantities in western Lincoln County.

Okfuskee County.—Practically all of Okfuskee County may be considered good prospective oil and gas territory. A small amount of oil has been produced in the northeastern part of the county, and very little drilling has been done elsewhere.

Seminole County.—Eastern Seminole County lies within the region within which oil and gas may be expected. In fact these products have been found at Wewoka, the county seat. Very little drilling has been done, and there is no means of knowing the extent of the deposits.

Pottawatomie County.—The chances for finding oil and gas in the greater part of this county are not good, because of the fact that practically the entire county lies within the Red beds area. The most likely place to prospect is in the vicinity of Keokuk Falls, in the northeastern part of the county.

Pontotoc County.—Northern Pontotoc County lies within the region occupied by Carboniferous rocks. Small amounts of gas have been found near Ada and Roff, and there are considerable deposits of asphalt near Ada. It is useless to attempt to find oil or gas in quantity in the southern part of the county, which lies within the region of the Arbuckle Mountains.

Hughes County.—All of Hughes County lies within the area occupied by Pennsylvanian rocks, and the chances are fairly good for finding oil and gas anywhere in the county. Very little drilling has been done, so that at the present time there is no means of knowing the exact location of possible productive pools.

Coal County.—Coal County lies within the area occupied by the Pennsylvanian rocks. Gas has been found in the northeastern part of the county, and it is very probable that drilling will reveal the presence of large amounts of oil and gas.

Pittsburg County.—Northern Pittsburg County lies within the region in which we may expect to find oil and gas. Several deep wells have been put down, and small amounts of gas have been secured. It is quite probable that more extensive drilling would reveal a larger amount. Southern Pittsburg County lies in the Ouachita Mountains where it is practically useless to attempt to find oil or gas.

Haskell County.—This county lies in the region of Pennsylvanian rocks. There are several anticlinal folds crossing the county from northeast to southwest. Gas has been found near Kinta, and it is probable that considerable deposits of both oil and gas will eventually come to light.

Latimer County.—Southern Latimer County lies within the area occupied by the Ouachita Mountains. Northern Latimer County lies within the area of Pennsylvanian rocks. Gas has been found near Red Oak, and other deposits will probably be found in the same general vicinity.

LeFlore County.—The southern part of this county lies in the Ouachita Mountain area; the northern half of the county, in the region of the Pennsylvanian rocks. There are several anticlinal folds which should contain oil or gas. Prolific gas wells have been discovered near Poteau, and are supplying that city with fuel. Other good wells have been found near Spiro. There is little doubt that more extensive drilling along the anticlines will reveal the presence of other deposits of gas, and probably of oil also.

Sequoyah County.—Southern Sequoyah County lies within the region of Pennsylvanian rocks, which should eventually yield considerable deposits of oil and gas. Gas has been found at Vian.

CONCLUSION.

These brief statements will indicate something of the future possibilities of the oil field. Judging from all available data it may be inferred that, at the present time, not one fourth of the prospective oil and gas territory has been carefully drilled, and not one tenth of the oil has yet been taken from the ground. A

considerable amount of prospecting has been done which has yielded no results, largely because of the fact that poor judgment was exercised in locating the wells.

With regard to the life of the field we can only conjecture. Relatively few of the wells of the state have yet ceased to produce. Many of the wells drilled ten years ago are still yielding a sufficient amount of oil to be profitable to operate. There is, at present, no definite way of estimating the ultimate life of the wells, but taking into account the structure of the sand, the quality of the oil, and the life of the wells in the older fields of the United States, where oil is produced under similar conditions, we need not be surprised if many of the wells now operating continue to produce oil for the next twenty-five, or even fifty years.

Additional wells are constantly being drilled in the developed fields, and new fields are constantly coming to light. It may confidently be predicted that the development of new fields will continue in Oklahoma for the next fifty years, and that they will continue to produce for another fifty years.

THE ORIGIN OF SULPHUR DEPOSITS.[1]

O. STUTZER.

TRANSLATED BY W. C. PHALEN.

In regions of present volcanic activity or where volcanic activity has but recently ceased, occurrences of sulphur incrustations are commonly observed. Steam and gases, smelling of sulphur dioxide are still emitted from the solfataras in these regions, and on the walls of their vents sulphur is being deposited.

Scientists were formerly inclined to attribute the origin of all workable sulphur deposits to the above agencies or processes. With more exact researches, these views have been shown in general to be incorrect. The bulk of, and the most important, sulphur deposits of the world have originated in other ways, which will be described presently. Only a few occurrences are of volcanic origin and of these, so far as the world's sulphur production is concerned, only the Japanese deposits are important. These were formed in old crater lakes or on the sides of old or at present active volcanoes.

The formation of sulphur in solfataras in zones of volcanic activity was thought formerly to be due to a reaction between hydrogen sulphide (H_2S) and sulphur dioxide (SO_2), whereby water was formed and sulphur set free. But as a result of the exact and detailed researches of Brun, another origin is shown to be the more probable.

Brun pointed out the impossibility of hydrogen sulphide (H_2S) and sulphur dioxide (SO_2) issuing together through the same vent.[2] If the reaction takes place, as intimated above, the

[1] The original article on "Sulphur" of which this is a part is contained in a published work entitled "Die Wichtigsten Lagerstätten der Nicht Erze." (The more important occurrences of the non-metallic minerals, Borntraeger Brothers, Berlin, 1911, pp. 474, Figs. 108.)

[2] A. Brun, *Chem. Zeitung*, No. 15, 1909.

two gases must have separate courses of exit, a condition which, in most cases, is precluded. According to his observations at Pico de Teyde, Canary Islands, as well as in Java, the sulphur appears to be present rather in the form of vapor or submicroscopic dust in a current of carbonic acid (CO_2). If the vapor is led into water below 100°, the sulphur condenses, forming milk of sulphur. If little water is present, the sulphur crystallizes at a temperature of 100° to 110° on the walls of the openings, gradually closing them. At higher temperatures (192° to 270°) the sulphur melts, flows out over the rocks and ignites. The origin of most of the Japanese deposits is explained by such processes.

The most important of the workable sulphur deposits of the world, however, bear no relation to vulcanism. They are rather typical sedimentary deposits. All these sedimentary types possess certain features in common, such as the constant accompaniment of gypsum, clay, limestone or marl, and bituminous substances. The fact that the accompanying rocks were deposited in shallow water is nearly always a phenomenon of such deposits. The common age, Miocene (Upper Miocene), of many of the occurrences must be regarded as more than fortuitous (Miocene; Sicily;[1] Romagna;[1] Marches;[1] Calabria;[1] Radoboj, Croatia; Swoszowice, Galicia; Kokoschütz, Upper Silesia; Sulphur, Louisiana; and others).

It may be said that the sulphur of the non-volcanic deposits has been formed chiefly through the oxidation of hydrogen sulphide according to the following reaction:

$$H_2S + O = H_2O + S.$$

The hydrogen sulphide necessary for the formation of this sulphur may have been produced either from the decomposition or decay of organic material or from the reduction of inorganic sulphates, chiefly gypsum, by means of organic substances. The reduction of inorganic sulphates could have occurred contempora-

[1] Considered by E. Kayser as belonging in the lower Pliocene (= Messinian) Formationskunde, II. Aufl., 1903, p. 520.

neously with the deposition of the sediments accompanying the sulphur, *i. e.*, through the action of the reducing substances on the freshly precipitated sulphate or the sulphate still in solution; or the reduction could have followed long after the deposition of the sulphate, when it had already become lithified.

The form of the sulphur deposits depends to a certain extent on the different modes of origin of the necessary hydrogen sulphide. Hydrogen sulphide, forming in a basin of deposition, will produce sedimentary sulphur deposits, if it produces sulphur deposits at all. But the hydrogen sulphide, resulting from the reduction of older sulphates, leads to the formation of the epigenetic occurrences, most of which have the form of veins. But if the latter hydrogen sulphide enters the basin, sedimentary deposits may form there also.

Sulphur veins of commercial importance are rare. E. Böse has described veins occurring at Conejos, Mexico, in Cretaceous limestone.[1] The central portions of these veins consist of sulphur bordered by a mixture of sulphur and silica. This in turn is bordered by sulphur mixed with gypsum, which passes into limestone. The silica along the border of the sulphur in these veins is regarded as having come from the siliceous limestone. Böse attributed the origin of the sulphur to sulphur bearing (H_2S) springs. The hydrogen sulphide was oxidized to water and sulphur in the superficial parts of these springs; and the presence of an excess of oxygen during the early stages of vein formation produced sulphuric acid which led to the formation of gypsum from the limestone.

At Gik-Salgan, south of Grossny, in the Caucasus, there are sulphur veins in limestone which have originated from sulphur springs. Numerous sulphur springs have been discovered in this region, though nothing definite is known with reference to the origin of the sulphur in them.

On the other hand, most of the other workable sulphur deposits, as those of Italy, Galicia, Louisiana, Upper Silesia, etc., have

[1] E. Böse, "Excursions aux Mines de Soufre de la Sierra de Banderas; Guide des Excursions du X Congrés Géologique International," Mexico, 1906, 11 pp.

formed contemporaneously with the country rock in shallow basins of deposition (*Flachseen*). They are therefore of sedimentary origin. The only proof of this is the bedded character of the sulphur.

In all the stratified deposits of sulphur, the sulphur beds are invariably confined to certain members of the series and do not occur in the form of irregular stocks or nests at different levels. In the Sicilian sulphur deposits, which are the most highly developed at the present time, massive gypsum, which does not contain a trace of sulphur, is present both in the hanging and foot walls of the sulphur-bearing beds. The hanging wall of the gypsum is a porous limestone, which contains no sulphur. An epigenetic explanation of the Sicilian deposits is bound to give a satisfactory explanation of this negative evidence, and up to the present time this has not been given. In this connection, the fact must not be lost sight of, that impervious marl occurs between the different sulphur-bearing layers. This would render the circulation of sulphur-bearing solutions very difficult, if it did not prevent it altogether.

In a word, the sulphur beds of Sicily present strong evidences of a sedimentary origin. The sulphur is either interfingered in the country rock which is marl or limestone, or is imbedded in it in the form of nodules or irregular masses, or is interlaminated in it in layers less than an inch thick. The last-named structure, which in Sicily is described as *Struttura soriata,* is especially conclusive evidence of a sedimentary origin. It is found also in Romagna and in Swoszowice, Galicia. The description of the latter deposits, published by the Austrian minister of agriculture, gives several illustrations of these banded occurrences (see Figs. 85 and 86).

It is possible to study this structure in detail at the Mine Gessolungo-Trigona, Caltanissetta, Sicily (see Fig. 87). Two sulphur beds are present here, a lower one about 10 feet (3 m.) thick and an upper one 13 feet (4 m.), separated by about 28 inches (70 cm.). The beds dip at an angle of 16°. They consist of regular parallel layers of pure native sulphur, less than

an inch thick, separated by layers of earthy limestone, of about double the thickness of the sulphur layers. They have been exposed in this mine for a distance of more than 650 feet (200 m.) and present one of the most beautiful examples which a mine could possibly afford.

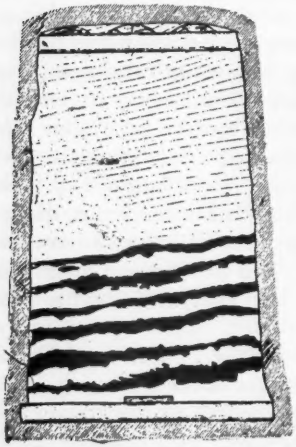

FIG. 85. Bedded deposit of sulphur in Swosozowice, Galicia. (After Ambrož.)

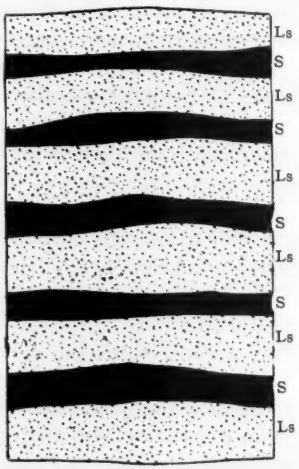

FIG. 86. Bedded sulphur-bearing rocks in the Solfara Grande di Sommatino Mine, Sicily. (After Mottura.) S = sulphur; Ls = limestone.

The parallel sulphur bands of these occurrences consist chiefly of compact sulphur. Occasionally they exhibit on their upper surface hollow spaces into which calcite crystals project. Sulphur crystals have also formed on this compact sulphur along these cavities. The hollow spaces, bordered below by sulphur and above by a layer of calcite, together with their accompanying crystals, have originated, through secondary solution and redeposition. The beautiful sulphur, gypsum, and celestite crys-

tals which the Sicilian mines have contributed to the mineralogical collections of the entire world are likewise secondary products, which have formed later along fissures, etc.

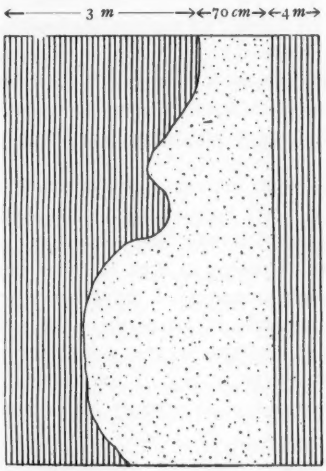

FIG. 87. Profile of the unconformable bedding of clay between underlying and overlying sulphur beds in the Gessolungo-Trigona Mine at Caltanissetta, Sicily.

The typically banded sulphur layers exhibit now at the Gessolungo-Trigona mine two phenomena which admit of satisfactory explanation only by accepting the view of primary sedimentary deposition of the sulphur. These are (1) typical cross-bedded structure (*Diagonalstruktur*) frequently repeated in vertical section, such as is often observed in sandstone; and (2) the erosion of the lower bed before the formation of the upper (see fig. 87). These phenomena are proof of the sedimentary origin of the sulphur. The theory that the thin layers of gypsum interbedded in the earthy limestone have been replaced is excluded in the above

cases, because the massive gypsum in the hanging wall of these occurrences reveals no sulphur.

The most difficult question which remains to be answered is by what chemical processes may the deposition of native sulphur in a shallow basin be explained. In the preceding paragraphs, it was shown that the sulphur of the bedded deposits had originated chiefly through the oxidation of hydrogen sulphide. This oxidation takes place by means of inorganic agencies according to the following reaction:

$$H_2S + O = H_2O + S,$$

or it occurs in the same manner with the aid of lower forms of life, of which more will be said later. The hydrogen sulphide necessary for the reaction may have come from organic sources, through processes of decay, as well as from inorganic sulphur compounds, through processes of reduction. Among the inorganic sulphur compounds, which occur to the writer, gypsum is the most important, and the organic substances necessary to its reduction are not absent in any of the known bedded sulphur deposits. The first reduction product which must be conceived as present in solution is the readily soluble calcium sulphide (CaS) the formation of which may be explained according to the following reaction:

$$CaSO_4 + 2C = CaS + 2CO_2.$$

The calcium sulphide thus formed decomposes in the presence of carbonic acid thus:

$$CaS + H_2O + CO_2 = H_2S + CaCO_3.$$

Another process of reduction was propounded by Hoppe-Seyler[1] in 1886. According to this process, the sulphate was reduced by methane in the nascent state. The methane was produced in the research from the fermentation of cellulose. The reaction probably takes place as follows:

$$CH_4 + CaSO_4 = CaCO_3 + H_2S + H_2O.$$

[1] *Zeitschrift für physiolog. Chem.*, 1886, Bd. 10, S. 401.

In nature, therefore, sulphates may be decomposed to hydrogen sulphide and finally, by oxidation of the latter, to sulphur.

The organic substances necessary for these reactions are present in the contemporaneous living plants and animals or they are introduced from below in the form of gases (*e. g.*, in Sicily by the distillation of bituminous sediments and in Kokoschütz, Upper Silesia, by gaseous emanations from coal beds).

Ochsenius[1] believed, contrary to most workers, that the sulphur originated from magnesium sulphate and sodium sulphate and not from gypsum. A part of the sulphur would then form as a result of decomposition of the magnesium sulphate (*Bittersalze*), present in the evaporating basin, by means of carbonic acid and hydrocarbons, developed from animal and plant organisms. The intermediate products of the reaction, according to Ochsenius, would be the corresponding metallic sulphide and hydrogen sulphide. A similar reaction occurs in a solution of magnesium sulphate in which straw or hay has been kept. A part of the sulphur of the magnesium sulphate in the form of sulphuric acid attacks the accompanying carbonate of lime, forming gypsum. The views of Ochsenius as to the original source of the commercial sulphur deposits have found few adherents.

Certain low forms of life, principally the so-called sulphur bacteria (*Schwefelbakterien*), have played a part in the formation of hydrogen sulphide and its reduction to sulphur. More will be given on this subject in conclusion. The development of hydrogen sulphide as a result of the influence of bacteria is a widespread natural phenomenon.[2] Thus the ordinary bacteria of decay and other microbes produce hydrogen sulphide in the decomposition of egg albumen. Other bacteria reduce sulphates and also produce hydrogen sulphide. In corresponding experiments performed in the absence of air, the sulphates were reduced at a temperature of 25–30° C. in 12 to 14 hours (Beijerinck). The reduction was explained by Murray and

[1] C. Ochsenius, *Zeitschr. f. prakt. Geol.*, 1893, p. 223 ff.

[2] Dr. W. Omelianski in F. Lafar, "Handbuch der technischen Mykologie," III. Bd., S. 214 ff., II. Aufl., Jena, 1904–1906.

Irvine[1] as resulting from the action of the carbon content of the protoplasm of the microbes according to the reaction:[2]

$$MSO_4 + 2C = 2CO_2 + MS.$$

The sulphide thus produced was then decomposed by carbonic acid, with the development of hydrogen sulphide:

$$MS + CO_2 + H_2O = H_2S + MCO_3.$$

Hydrogen sulphide may collect in large quantities as a result of similar processes in natural seas or lakes, examples of which may be given. In the water of Wiessowo Salt Lake, Government of Charkow, Russia, Nadson found the following amounts of hydrogen sulphide in a liter of water at the depths indicated:

Depth.	Ccm H_2S.
52 feet (16 m.)	5.91
59.4 feet (18.1 m.)	88.31
61.3 feet (18.7 m.)	184.96

According to Lebedinzeff[3] the following quantities of hydrogen sulphide are contained per liter in the water of the Black Sea:

Depth.	Ccm. H_2S.
700 feet (213 m.)	0.33
1,400 feet (427 m.)	2.22
6,650 feet (2,026 m.)	5.55
8,290 feet (2,528 m.)	6.55

At considerable depth, therefore, the water of the Black Sea contains twenty times as much hydrogen sulphide as near the surface. This results "from the decomposition, under the influence of anaerobic bacteria in the presence of sulphates in the sea water, of the organic substances, deposited on the sea floor."

[1] *Transact. of the R. Soc. of Edinburgh*, 1893, Vol. 37, p. 496.

[2] "M" indicates a bivalent metal. In its place, may be used Ca, etc., when gypsum or any other definite sulphate is employed as the source of the sulphur.

[3] "Travaux de la Soc. des naturalistes à Odessa," 1891, Vol. 16 (Russian).

This enrichment in hydrogen sulphide of the waters of the Black Sea at depths is attributed by Andrussow to the complete lack of vertical circulation. For the latter reason no living fauna exist in the deeper parts of the sea, since animal life depends on the circulation of the water, but principally on the presence of a certain amount of oxygen in it.

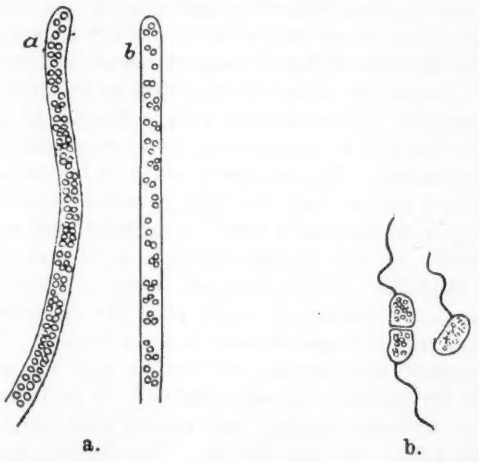

FIG. 88. Sulphur bacteria. (*a*) Beggiatoa Alba, greatly enlarged. (After Windogradsky.) (*b*) Chromatium Okeini, greatly enlarged. (After Cohn.)

An unlimited increase in hydrogen sulphide, which is very poisonous for higher organisms, is fortunately checked by the reverse process, *i. e.*, by oxidation. Such oxidation takes place as a purely chemical process under the influence of atmospheric oxygen. Hydrogen sulphide dissolved in water is by this means converted into water and sulphur in a finely divided condition, which is subsequently oxidized to sulphur dioxide (SO_2). In nature this process is stimulated in an energetic manner by the action of another kind of sulphur bacteria. In contrast to the

bacteria which form hydrogen sulphide and to those which exert a reducing influence already described, the bacteria under discussion exert a strong oxidizing influence. They are distinguished from all other bacterial forms through their peculiar property of secreting drops of sulphur in their protoplasm, by the oxidation of which they receive the energy necessary for life.[1]

The researches of Winogradsky[2] have firmly established the fact that these bacteria oxidize hydrogen sulphide and deposit the separated sulphur in their cells in the form of oily globules. This sulphur on the death of the cell is converted into the crystalline variety. The sulphur makes up more than 90 per cent. of the bulk of the cell. The oxidation (*Atmung*, breath) of this sulphur is the source of energy necessary to the maintenance of the life of the bacteria. The carbonates, taken up by the bacteria, but which are not necessary for their existence, neutralize the sulphuric acid produced as a result of oxidation and sulphates are produced. By this process, therefore, carbonates are converted to sulphates. Finally, these are reduced by organic substances, *e. g.*, the remains of higher plant life or certain rod-like bacteria, and hydrogen sulphide is again formed. The hydrogen sulphide then supplies the bacteria with the material needed for the production of more sulphur.[3] If the bacteria are deprived of hydrogen sulphide, they oxidize their secreted sulphur within a day or two and then die. These bacteria are found not only in nearly all sulphur springs, but also in the mud of most waters, where hydrogen sulphide is developing as a result of the decomposition of organic albuminoids or of the reduction of sulphates.

The life of the bacteria requires the presence of two gases, hydrogen sulphide and oxygen, which in consequence of the ease of oxidation of hydrogen sulphide are mutually exclusive or incompatible. The bacteria therefore must be confined to that re-

[1] See also Abstracts, by Doss, on the works of Jegunow, Sidorenko und Sokolow. *Neues Jahrbuch fur Min., Geol. u. Pal.*, Stuttgart, 1900, S. 225.

[2] *Botanische Zeit.*, Jahrgang 45, Nr. 31–37, 1887.

[3] The entire process has been called by Stutzer *Krieslauf des Schwefels, i. e.*, circulation of the sulphur.

stricted zone into which penetrate oxygen from above and hydrogen sulphide from below.

Still another group of bacteria are the thionic acid bacteria, which secrete no sulphur in their cells but which oxidize thiosulphates to tetrathionic acid and sulphuric acid. In the latter reaction, sulphur separates as indicated below:

$$Na_2S_2O_3 + O = Na_2SO_4 + S.$$

The thiosulphate may be replaced by hydrogen sulphide or still better by calcium sulphide.[1]

[1] See also Beijerinck, *Centralblatt für Bakt.*, 1904, Bd. II., S. 563.

THE TRANSPORTATION AND DEPOSITION OF GOLD IN NATURE.

VICTOR LENHER.

Of all the factors which play an important part in the genesis of ore deposits, the agency of solution is perhaps the most fundamental for it is by solution that the chemist is able to study and to attempt to imitate the chemistry of ore deposition as carried out in nature. Any information that will throw light on the character of possible ore-bearing solutions may be expected to aid in studying the many problems incident to the solution, transportation, and deposition of the metallic ores.

In connection with some recent chemical studies which have been made with gold, certain solutions have been worked with, the deportment of which toward various reagents as well as with certain minerals, indicates a degree of stability which appears to be of geological significance. Indeed certain gold solutions possess a stability from the purely chemical standpoint which one would not be likely to expect from our general knowledge of the ease with which gold is deposited out of most of its solutions by even the mildest reducing agents.

How gold is dissolved and transported in underground waters has not been clearly shown. The suggestive work of Stokes (ECONOMIC GEOLOGY, I., p. 650, 1906) on the solubility of gold in cupric chloride or in ferric chloride solutions at 200° with the redeposition of metallic gold on cooling, appears to afford a possible means of transportation of gold solutions at elevated temperatures with the subsequest deposition of the gold by lowering of the temperature. The work of Emmons on "The Agency of Manganese in the Superficial Alteration and Secondary Enrichment of Gold-Deposits in the United States" (*Trans. Amer. Inst. Min. Eng.*, 1910, 767) together with the work of McCaughey (*Jr. Amer. Chem. Soc.*, 31, 1,263, 1909), and Brokaw (*Jr. of*

Geol., Vol. 18, 321, 1910), as well as the earlier work of Pearce (*Trans. Amer. Inst. Min. Eng.*, 22, 739, 1893), Rickard (*Trans. Amer. Inst. Min. Eng.*, 26, 978, 1896), McIlhiney (*Amer. Jr. Sci.*, 1896, 293), and Don (*Trans. Amer. Inst. Min. Eng.*, 27, 599, 1897), apparently require that free chlorine is the solvent for the gold in the first instance, or if not free chlorine, a solvent whose powers are practically equivalent to that of free chlorine. When the chloride solution of gold is the transporting solution, it seems obvious that the gold is subsequently deposited as metal by a reducing agent. The agency of manganese in the solution of gold and its transportation is consistent in many gold deposits with the accompanying manganese deposits and throws considerable light on the superficial transportation of gold.

The solubility of gold in such media as the alkaline cyanides can hardly be deemed of material importance from the viewpoint of a natural transporting solution. The action of concentrated sulphuric acid or strong phosphoric acid in the presence of oxidizing agents on gold will cause solution (Lenher, *Jr. Amer. Chem. Soc.*, 26, 550, 1904) but this solvent action requires a higher concentration of acid than can be expected in nature. Similarly though hydrochloric acid under pressure (Lenher, ECON. GEOL., 4, 562, 1909) and nitric acid (Dewey, *Jr. Amer. Chem. Soc.*, 32, 318, 1910) at atmospheric pressure dissolve gold, the solution occurs only in concentrated acids, and the facts are of no importance in seeking for natural solvents for gold.

From all of these acid solutions the precipitation of the gold is usually assumed to take place by ferrous sulphate, metallic sulphides such as pyrites, or, in the case of Stokes' experiments, by lowering of the temperature.

The alkaline solutions which can dissolve and carry gold have not as a rule received as serious consideration as transporting media as the better known chloride solutions. Indeed the literature on alkaline gold solutions is very meager. This is particularly true in regard to the alkaline sulphide solutions.

That gold can be brought into solution by means of the alkaline sulphides has long been known, but it is doubtful if the geolog-

ical significance of the resulting solutions has been fully appreciated.

Probably at least as early as the time of Glauber it was known that gold can be rendered soluble by fusion with liver of sulphur. Stahl in the seventeenth century ("Observations Chymico-Physica Medicæ") is the first to bring out the fact clearly, and in doing so suggests that Moses burned the golden calf with sulphur and alkali and gave the solution to the children of Israel to drink.

In more recent times, Skey (*Trans. New Zealand Institute*, 5, 382, 1872) in studying the formation of gold nuggets in drift suggests the solution of gold in the alkaline sulphides as the medium by which gold can be carried. Eggleston (*Trans. Amer. Inst. Min. Eng.*, 9, 640, 1880–1881) in studying the formation of gold nuggets and placer deposits found spongy gold to be soluble in the alkaline sulphides. Becker (*Amer. Jr. Sci.* (3), 33, 207, 1887), in his studies on the mercury deposits of the Pacific coast, has shown that gold dust dissolves in sodium sulphide. He believed that some of the gold veins bear so considerable a resemblance to the quicksilver deposits that like the latter they were formed by precipitation from solutions of the soluble double sulphides. Liversidge (*Journal of the Royal Society of New South Wales*, 27, 303, 1893), in studying the question of the origin of gold nuggets, reviews the earlier work on the solubility of gold and finds it to be soluble in sodium sulphide.

These solubility experiments have been repeated in our laboratory and the fact corroborated that metallic gold is soluble in solutions of the alkaline sulphides. More significant, however, appears the fact that from these solutions of gold in the alkaline sulphides, iron pyrites will not throw out the gold.

As is well known, the metals, the metallic sulphides, and even many kinds of organic matter will precipitate gold from the solution of gold chloride. In the case of the alkaline sulphide solutions containing gold, neither pyrites nor metallic iron will precipitate the gold, but on the other hand, gold deposits out of these solutions by exposure of the solution to the air, under which condition the sulphide oxidizes.

The sulphide solutions of gold are permanent stable solutions to the ordinary reducing agents, that is, to such reducing agents as precipitate gold from the chloride solution. These alkaline sulphide solutions deposit their gold content by contact with acid or by exposure to oxidation. Not only are the alkaline sulphide solutions of gold stable to the metallic sulphides, but experiments made in sealed tubes have demonstrated that sodium, potassium, ammonium, or calcium sulphide solutions will dissolve gold leaf in the presence of pyrites without any deposition whatever of gold on the pyrites.

It is therefore obvious that through the agency of the alkaline sulphides it is possible for gold to be transported in alkaline sulphide solution through a bed of pyrites without deposition of metallic gold, and indeed it is possible to think of such a water passing through a bed of gold-bearing pyrites actually enriching itself by solution of the gold from the pyrites. To follow such a solution farther, it can be conceived that gold can be carried through a reduced zone and later the gold can be deposited by meeting acid in the reduced zone, or in absence of acid can be carried indefinitely until it reaches a zone of oxidation when the metal would be deposited.

When sodium thiosulphate is allowed to act on gold in the presence of oxygen, the double thiosulphate of gold and sodium is formed. This double thiosulphate is also formed when auric chloride and sodium thiosulphate are brought together in solution. This salt possesses remarkable stability in that the dilute acids, hydrochloric or sulphuric, do not at once decompose it, nor does ferrous sulphate or oxalic acid, two of the most common precipitating agents for gold, reduce it to metallic gold at once. All of these reagents do in time or in stronger solutions precipitate the gold from this thiosulphate compound. The extraction of metallic gold from silver ores in the thiosulphate extraction process depends on the formation of the double thiosulphate (Stetefeldt, "The Lixiviation of Silver Ores with Hyposulphite Solutions," pp. 15, 38).

These thiosulphate solutions are reasonably stable to iron pyrites, but on standing, metallic gold slowly deposits on the pyrites.

The sulphite solutions of gold are another example of a means in which gold can be held in alkaline solution. Curiously enough the double sulphite of gold and ammonium is quite stable, while the double gold sulphites of the alkalis are not nearly so stable.

Von Haase (*Chemiker Zeitung*, 535, 1869) has studied the double sulphite of gold and ammonium. Haase worked in ammoniacal solution and was able to crystallize the double salt out of solution. The ammoniacal solution as prepared by Haase has been made and has been found to be quite stable to iron pyrites and to metallic iron. Ammoniacal sulphite solutions have been preserved for months in stoppered flasks and when tested from time to time by withdrawing small portions and acidifying, metallic gold is instantly precipitated. These ammoniacal sulphite solutions when sealed in tubes with iron pyrites or with metallic iron deposited no gold in months.

Both the sodium and potassium gold sulphites have been described by Haase. In solution, these salts are more unstable than the corresponding ammonium compound. The sodium as well as the potassium gold sulphite solutions yield gold to pyrites by a few minutes' contact. In reality a small quantity of the potassium or sodium gold sulphite added to the ammonium gold sulphite solution increases very much the instability of the latter toward reducing agents; indeed it is only necessary to add a small quantity of the sodium or potassium compound to the ammonium salt to cause the latter to lose its gold to pyrites practically as readily as though no ammonium salt had been present. This tendency on the part of the fixed alkalis to increase the instability of the ammonium gold sulphite solutions would seem to indicate that the sulphite solutions are not so plausible a means of transportation of gold in underground waters, inasmuch as in most natural waters sodium and potassium salts are present, while ammonium salts are found only in traces. Indeed natural ammoniacal solutions free from the alkalis are quite unknown.

The alkaline solutions of gold in the lower form of valence of gold, namely the aurous state, present some interesting phenomena when considered from the viewpoint of transportation of gold.

The aurous state of gold is produced when the ordinary or auric salts are reduced in a certain definite manner. The agencies by which this lower state of oxidation of gold can be produced are limited.

Aurous chloride and bromide are produced by the action of a moderate heat on the ordinary auric chloride or bromide. Experiments made recently in this laboratory show that by proper control sulphur dioxide, one of the best laboratory reducing agents and one of the common reagents used to precipitate gold from solution, can be used to effect the reduction of gold from the auric to the aurous state.

When sulphurous acid is added to a neutral or acid solution of gold without having present some other salt, it is very difficult to stop the reduction of the auric form of gold at the aurous state, the tendency being to produce complete reduction with the precipitation of metallic gold. If, however, a large excess of any of the alkaline chlorides, calcium, magnesium or zinc chlorides, be present, the reduction of the auric form of gold to the aurous state by means of sulphurous acid can be readily controlled. When an ordinary auric chloride solution is treated with a large excess of one of the above mentioned chlorides, and the solution then treated with a solution of sulphurous acid, the amber yellow color of the auric chloride gradually fades until the solution is rendered completely colorless. This colorless stage represents the existence of the aurous form of the gold, and the gold exists in this solution in all probability as a double aurous chloride.

Solutions of gold prepared in the manner indicated are far more stable under certain conditions than the ordinary auric chloride solutions. These conditions in which marked stability has been observed are somewhat curious. When such a solution is kept out of air contact and when no free acid or at most very little free acid is present, the solutions are fairly stable; if, however, the solution is exposed to the air, gold begins slowly to deposit. As far as the experiments have gone on this line, it seems as though the precipitation of metallic gold from this par-

tially reduced solution when exposed to the air is due to autoreduction to metallic gold by the oxygen of the air.

The partially reduced or aurous solution out of air contact is far more stable to pyrites than the ordinary or auric compounds. Here again is a suggestive solution so far as transportation of gold is concerned.

Of the various means of solution and transportation of gold which have been observed, it would appear that the alkaline sulphide solution may with study solve some at least of the problems of gold deposits. At all events, a solution is known which will not lose its gold to pyrites and yet will transport gold. The alkaline sulphides can easily be conceived as important natural solvents, and while other alkaline solutions such as the aurous solutions possess considerable stability, yet their formation in nature would not appear to be so likely as the sulphide solution.

HYDROTHERMAL ALTERATION OF GRANITE AND THE SOURCE OF VEIN-QUARTZ AT THE ST. ANTHONY MINE.

ELWOOD S. MOORE.

INTRODUCTION.

In presenting this article the writer does not claim originality for the discussion of hydrothermal alteration, since the works of Lindgren, Steidtmann and others on this subject are familiar to most geologists. The quartz-veins, however, present some rather definite evidence regarding their origin as the analyses and figures presented below indicate, and although the subject of hydrothermal alteration is not a new one, every additional description of rocks illustrating this phenomenon strengthens our theories on ore deposition. It is therefore with the hope of supplying another example of this type that the following statements are presented. The writer's first intention was to make this article a comparison of the results of hydrothermal and weathering action on granites and with this object in view the three analyses on weathered granite were made. It was found however that insufficient data was at hand and these analyses are given near the close of this discussion in order that they may be on record for future reference by those who are interested in this subject, although they have no direct bearing upon the title of this paper.

I am indebted to Professor Logo, of the chemistry department of the Pennsylvania State College, for the analyses, which were made under his supervision. The specimens were chosen so as to be as representative as possible, although such work may always be open to the criticism that the amount of rock which can be transported for such purposes is limited.

The St. Anthony is the principal mine in the Sturgeon Lake gold field, located in northwestern Ontario. A description of

this field, by the writer, was published in the report of the Ontario Bureau of Mines,[1] in 1911, but since this report was prepared the chemical analyses and other data have been obtained and presented here for the first time.

THE GEOLOGY IN THE VICINITY OF THE MINE.

The formations in the vicinity of the mine are all pre-Cambrian and consist chiefly of igneous rock. The mine is situated on the contact of a great mass of granite and a large area of Keewatin greenstones, acid eruptives, and schists, the latter derived mostly from metamorphosed graywacke. The

FIG. 89. Showing numerous fragments of Keewatin basic rock in the granite.

granite, known as the Sturgeon Lake granite, intrudes all of the Keewatin rocks and has usually been considered of Laurentian age, although it may be later. A mile or more from the contact

[1] "The Sturgeon Lake Gold Field," *Ont. Bur. of Mines,* Vol. XX., pp. 133–157.

the composition is typical of granite but as the contact is approached the rock becomes more basic, evidently on account of the absorption of considerable basic Keewatin rock. Evidence of the "stoping" action of the granite is well illustrated in Fig. 89, which shows numerous fragments of the basic rock in the granite. The composition of the basic phase is that of a granodiorite and in many places it is strikingly porphyritic.

The veins in the area consist chiefly of quartz but calcite and siderite are also found, the two latter being more common in the basic schists than in the granite. The greater amount of these minerals in the schists is probably due to the fact that the feldspar supplied considerable of the calcium and also because the basic action of the wall rocks tended to precipitate the calcite from the solutions in the vein by mass action. The ore consists of pyrite, free gold, sphalerite, galena, and chalcopyrite and the proportion of free-milling gold to the concentrates decreases with depth.

DESCRIPTION OF THE GRANITE AND QUARTZ-VEINS.

The granite of the main area is of ordinary type. It contains orthoclase, microcline, albite, quartz, and biotite, with pyrite as the chief accessory mineral. There are spots however which are higher in soda than the main mass and this is particularly true near the contact with the Keewatin rocks. The absorption of the Keewatin seems not only to have increased the sodium content but also to have caused a disturbance in the chemical equilibrium of the granite magma which resulted in a considerable amount of differentiation. The granite is also strongly porphyritic in the disturbed area due to the conditions of cooling and saturation of the magma by the sodic feldspar compound, which formed the phenocrysts. A specimen (No. 289) taken on St. Anthony bay, one quarter mile from the mine, showed the following composition.

	Per Cent.
SiO_2	65.55
Al_2O_3	22.01
Fe_2O_3	2.46

CaO	2.34
MgO	0.51
Na_2O	4.92
K_2O	1.53
Total	99.32

In this analysis the high percentage of alumina and sodium and the low percentage of silica and potash are striking features. The mineralogical content shows orthoclase, albite, biotite and quartz. The albite is comparatively fresh but the orthoclase is

FIG. 90. Quartz veins in the granite at the St. Anthony mine.

more altered and pitted with flakes of sericite. The rock has suffered some regional metamorphism.

Extending along the contact between the granite and Keewatin there is a greatly disturbed zone where numerous fissures were formed in the granite by the contracting of the rock on cooling and by its shrinking away from the adjacent rocks at the contact. These fissures are filled with quartz-veins or quartz and feldspar

dikes. At the St. Anthony mine and extending a quarter of a mile to the westward the granite has been completely shattered and filled with a network of quartz-veins. These are extremely irregular and have the appearance of having segregated from the granite, since they grade over and are lost in it (Fig. 90).

One large vein which has been mined for a width varying from 10 to 25 feet begins in the granite and follows a fissure in the Keewatin schists to the lake shore. This vein has irregular walls in the granite and is connected with numerous smaller veins.

While the granite has all suffered considerably from ordinary weathering, the remarkable change in its appearance close to the fissures in this particular area seems to leave no doubt that a large amount of hydrothermal action has taken place since the rock has been almost completely altered to a protogene, *i. e.*, a rock consisting of quartz and muscovite. The extent of the alteration varies greatly, since it may be observed from an inch to 10 or 12 feet from the veins. The chief sulphides which occur in the veins are pyrite, galena, sphalerite, and chalcopyrite and the gold accompanies these except when separated by secondary enrichment processes. The pyrite is undoubtedly pyrogenetic in the granite and in close proximity to the veins seems to have been leached out to some extent and carried into the veins with the quartz, since it is more plentiful in many other places in the granite than close to the veins. In other cases the vein walls are impregnated with the sulphides.

ALTERATION OF THE GRANITE.

To obtain data on the changes produced by the solutions which circulated in the fissures described above, several specimens were collected of which chemical analyses were made. The first (No. 337) was taken far enough from the vein to obtain what appeared to be the freshest type of granite in the vicinity. It shows a little sericite, pyrite, and chlorite, but it is remarkably different from the highly altered type next described. The third (No. 335) was obtained close to the vein and it consists of a yellowish-green, almost greasy mass of scaly mica, believed to be both

sericite and paragonite, impregnated with quartz stringers. The rock might be called a protogene. The second specimen (No. 336) was taken between the other two and represents an intermediate stage in alteration. From these rocks the following analyses were obtained.

	I.	II.	III.	IV.
SiO_2	72.63	72.04	70.22	61.67
Al_2O_3	17.11	18.76	20.44	27.38
Fe_2O_3	1.81	2.08	2.38	.55
CaO	.81	.35	.57	.82
MgO	.30	.52	trace	.36
Na_2O	3.65	3.86	5.12	(8.27)
K_2O	3.00	1.73	.74	
S	.32	.10	Not det.	.05

Analysis I. was made from specimen No. 337, the fresher rock; II. from 336 the intermediate type; III. from 335, the most highly altered type; and IV. from 335 after as much of the vein-quartz as could be conveniently removed was extracted before grinding. The object in making the latter analysis was to determine whether much silica had been introduced into or subtracted from the granite in the development of the veins. The result would indicate that there was considerable loss of silica and it also shows that the iron and possibly the sulphur are chiefly in the unaltered granite or in the veins, having been leached from the granite forming the vein walls.

A comparison of the analyses shows a regular decrease in the silica content of the granite indicating a transfer to the veins. An increase in alumina may be accounted for in the large increase in sericite which carries 38.5 per cent. compared with 18.4 per cent. in orthoclase, the mineral which has been replaced and which formed a large portion of the original rock. The difference in silica and potash may also be explained on the assumption that if the alumina of the orthoclase remain constant considerable silica and potash would be lost in the transformation of orthoclase into sericite, since the former carries 64.7 per cent. of silica and 16.9 per cent. of potash compared with 45.2 and 11.8 per cent. of these constituents in the latter mineral.

The high percentage of soda and low percentage of potash shown in the analyses indicate that the greater portion of the scaly mica must be paragonite instead of the sericite which commonly occurs as the alteration product of granite, since the most highly altered specimen shows no other mineral which could carry the soda in quantity. Sericite and paragonite cannot readily be distinguished under the microscope and the appearance of the rock favors the occurrence of paragonite instead of sericite in so far as various descriptions of the two minerals show any difference in character. The descriptions given above for the percentage changes involved in the transformation of orthoclase into sericite would hold equally well, although in different proportions, for the alteration of albite into paragonite.

The decrease in potash and silica and increase in soda seems to be contrary to the conditions specified by Mr. Steidmann in his article on the alteration of rocks.[1] There is a regular decrease in lime as stated by this author and an increase in iron seems to be due to the introduction of sulphides in the veins. While some of the results obtained from these analyses better fit the conditions usually produced by ordinary weathering action, others are quite contrary to them and it must be accepted as an irregular case or one in which hydrothermal and weathering actions have combined. From statements previously made there seems to be no doubt that hot solutions have influenced to a large extent the rocks close to the veins.

A microscopic study of the rocks analyzed gives the following mineralogical compositions. No. 337, the fresh specimen, contains albite, in large amount, orthoclase, quartz, muscovite, apatite and pyrite. The orthoclase shows slight evidence of the development of sericite while the albite is comparatively fresh. A few small irregular crystals of apatite are seen and the pyrite is largely altered to limonite. The pyrite has every appearance of being pyrogenetic in the rock. In one case limonite occurred as small, cubic pseudomorphs after pyrite. The muscovite exists

[1] "A Graphic Comparison of the Alteration of Rocks by Weathering with their Alteration by Hot Solutions," ECON. GEOL., Vol. 3, pp. 381–407.

in two forms, the scaly sericite variety occurring chiefly in cracks, and larger laminæ of the ordinary type scattered throughout the section. A little chlorite is associated with the mica in some of the cracks. Since the texture of the specimen is similar to that of an ordinary granite no illustration is shown.

FIG. 91. A section from specimen 336 showing the complete transformation of orthoclase into sericite, only the crystal outline of the feldspar remaining. Crossed nicols (× 45).

In specimen 336 the feldspars have nearly all decomposed, only a little microcline remaining. They have almost entirely changed to sericite or paragonite and free quartz, in some cases the outlines of the former crystals being preserved in the scaly mica (Fig. 91). The latter mineral also lies along cracks while flakes of muscovite are scattered throughout the section. Several crystals of apatite, highly fractured and surrounded by quartz and scaly mica, the latter often filling the cracks in the apatite, are seen. A stain of iron oxide along planes of weakness is common and a few very small fragments of pyrite, showing a coating of

limonite, or completely replaced by the latter, are sprinkled through the slide. There is very little evidence of any kaolin developed in this rock.

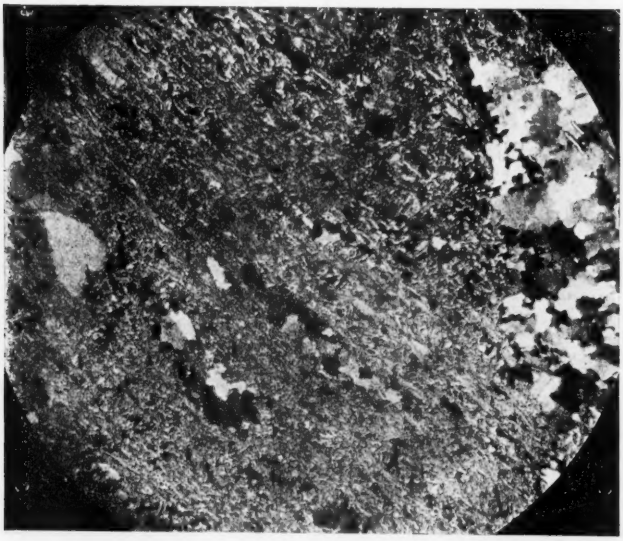

FIG. 92. A section from specimen 335 showing the segregation of the quartz into stringers. Crossed nicols (× 45).

The chief difference between the thin section from specimen 335 and that from 336 lies in the loss of all evidence of feldspars, including their crystal outlines, and the recrystallization of the quartz, together with a tendency for the latter to segregate into stringers (Fig. 92). No apatite was seen and only one small speck of pyrite which showed comparatively little alteration.

The appearance of the specimens described above suggests a strong resemblance to some of the descriptions of rocks quoted by Lindgren in his well-known paper on "Metasomatic Processes in Fissure-Veins." In Vogelgesange's description of the Freiberg veins he speaks of the silvery white color of the mica con-

nected with a chloritic appearance and this is very characteristic of these specimens.[1] As already stated the analyses would indicate that much of this mica must be paragonite, the soda variety.

The conclusions reached regarding the alteration of the granite around the St. Anthony mine are as follows: The most important changes in chemical composition are in the loss of silica which seems to have served, to some extent, to build up the quartz veins; the relative increase of alumina, the loss of calcium, potash, and sulphur, and the increase of iron and soda. The chief mineralogical changes are in the alteration of the feldspars to scaly mica, sericite and paragonite; the recrystallization of the quartz and its partial segregation into veins; the oxidation of the pyrite and its removal, to some extent, from the rocks adjacent to the veins; the introduction of sulphides with the vein-quartz.

As stated in the introduction to this paper the following chemical analyses of granite altered by weathering action are given here chiefly for record, since they do not bear directly upon the subject of this paper. The specimens were collected near Black Sturgeon river, which enters Black bay on Lake Superior, and for the purpose of studying the transformation of some of the Laurentian granite to Keweenawan shale. There is good evidence that some of this shale has been formed by the decomposition, in situ, of the granite, since there is a gradual gradation from the solid granite through decomposed granite to a shale and sandstone. The increase in silica in the analysis of specimen No. 408 is due chiefly to the introduction of a few sand grains and the increase in iron is due to seepage from overlying rocks. The specimens illustrate very well the terrestrial character of at least some of the Keweenawan sediments, but they proved rather unsatisfactory for chemical analyses, unless a great amount of rock could be treated, on account of the very irregular texture of the granite.

The results of the analyses are as follows:

[1] *Transactions Amer. Inst. Min. Eng.*, Vol. XXX., pp. 659-660.

	403	406	407	408
SiO_2	63.52	65.57	64.34	71.48
Al_2O_3	23.57	23.92	25.57	21.94
Fe_2O_3	2.01	0.37	0.28	2.23
FeO	0.17	0.104	0.13	
MgO	0.68		0.20	0.81
CaO	2.91	1.51	0.81	1.28
Na_2O	5.09	6.08	0.35	
K_2O	1.28	2.26	5.75	
H_2O	0.91	1.01	1.07	
Above 105°				
H_2O	0.09	0.01	0.56	
Below 105°				

No. 403 is the least altered specimen and the others run in order, No. 408 being a reddish shale and 407 partly shale and partly granite. The chief mineralogical changes produced in these specimens are the decomposition of the ferro-magnesian minerals with the development of chlorite and its final disappearance and the change of the feldspar to sericite and kaolin. There is a greater tendency for kaolin to form in these rocks than in those described above which have been altered by hot solutions. The potash feldspar is almost invariably the first of the feldspars to show decomposition.

THE GEOLOGY OF THE GRAPHITE DEPOSITS OF PENNSYLVANIA.

BENJAMIN L. MILLER.[1]

LOCATION.

The graphite deposits of Pennsylvania are located in the Piedmont Plateau of the southeastern part of the state and are contained in greatly metamorphosed pre-Cambrian and early Paleozoic rocks. These rocks are represented in the following ten counties: Northampton, Philadelphia, Lehigh, Berks, Montgomery, Chester, Delaware, Lancaster, and York. Graphite has been found in all but the last-named county, while mines or prospects have been opened in Chester, Berks, Lehigh, and Bucks counties. For several years all operations have been confined to the valleys of Pickering and French creeks, Chester County, lying within the Phoenixville quadrangle of the United States Geological Survey.

HISTORY.

It is not known when graphite was first mined in Pennsylvania, but there seems to be little doubt but that the deposits of Bucks County were worked about the middle of the eighteenth century. The locality is about three fourths of a mile north of the present village of Trevose. In the early part of the last century the mine was re-opened though little work was done. Some deposits a short distance east of the present town of Langhorne were also worked at an early date.

In Chester County the first graphite mine to be opened was near Pughtown near French Creek. Rogers, in his final report on the "Geology of Pennsylvania," published in 1858, gives a brief description of the workings, the cleaning of the flake, and

[1]Published with the permission of the State Geologist of Pennsylvania.

the uses of the material. About the same time a mine was opened about one mile east of Vera Cruz station, Lehigh County, which was at first operated for gold but later for graphite. The pyrite and marcasite associated with the graphite were either mistaken for gold or else contained small amounts of gold.

Although we lack information concerning the early attempts to mine graphite in Pennsylvania, it is probable that the entire amount mined prior to 1870 was of little consequence. During the seventies, however, there was an increase of interest in graphite mining and several mines were opened near Boyertown, Berks County, and in Pickering Valley, Chester County. During the eighties, several graphite mines in Chester and Berks counties were worked intermittently but with small production. The boom in the graphite industry began about 1895 and for the succeeding twelve years many graphite mines were opened in Chester, Berks, and Lehigh counties and many more localities prospected. During that period several of the mines were operated on a profitable basis but the business, as a whole, suffered greatly through unscrupulous promoters and poor business management. Within the past few years the industry has declined considerably and at present there are only two mines in operation, both located in Chester County. The reason for the decrease of operations is due almost entirely to the difficulties encountered in the separation of the graphite from its associated minerals. The supply of graphite-bearing rock is practically inexhaustible, but the concentration of the flake presents problems that have not as yet been economically solved by most of the producers. The market for the finished product has also been somewhat unreliable. Nevertheless, Pennsylvania for many years has occupied second rank in the list of the graphite-producing states of the Union. Its production is exceeded only by that of New York, in which state the graphite comes almost entirely from one mine, extensively worked by the Dixon Crucible Company.

DESCRIPTIONS OF THE CONTAINING ROCKS.

The graphite deposits of Pennsylvania are confined entirely to sedimentary rocks that have undergone a great degree of metamorphism, or to igneous dikes that cut such rocks. In increasing order of importance the graphite is found in sandstones, gabbros, limonite iron ores, basic gneisses, crystalline limestones, and acid gneisses. Numerous pegmatite dikes are intimately associated with the last-named group of rocks. Thus far graphite in paying quantities has been found only in the crystalline limestones and the acid gneisses.

Sandstone.—In northern Chester County Dr. E. T. Wherry has reported the presence of graphite in Cambrian sandstone. The occurrence is of interest because of the statement, frequently made, that graphite does not occur in unmetamorphosed sediments. Emerson also has described[1] an unmetamorphosed Triassic sandstone in Massachusetts that contains "scales of graphite in considerable number." In both cases the graphite was obtained from nearby metamorphic rocks of greater age.

Gabbro.—Gabbro dikes cut the graphite-bearing sedimentary rocks in many places and in several places graphite has been noted in the outer portions of such dikes. Some specimens of this kind were obtained from the old graphite mine near Trevose. There is no doubt but that the carbon was picked up and included within the igneous rocks in its passage through the sediments in which carbonaceous matter was present. The graphite is in rather large flakes of good quality.

Limonite Iron Ores.—As will be described later, the graphitic gneisses of Pennsylvania carry considerable pyrite and pyrrhotite which on surface oxidation form limonite. In several places in the Pickering Valley of Chester County residual limonite iron ore deposits have been formed by the decomposition of the gneisses at the surface and the concentration of the limonite derived from the iron sulphide minerals. In the decomposition of the original rocks graphite is the only mineral that has remained unchanged. Even the greater portion of the quartz has been removed and the

[1] Monograph No. XXIX., U. S. Geol. Survey, p. 365.

residuum consists of yellow clay, nodules of limonite, and flakes of graphite that are abundant in both the clay and the iron ore. In one instance an attempt was made to concentrate the graphite from the residual clay that had been washed out of the iron ore by log washers when the iron mines were in operation, but the project was not successful. The flakes are of average size and bright, having apparently undergone no change in the decomposition of the containing rocks.

Basic Gneisses.—In several places in Berks County basic gneisses have been observed in which there are abundant flakes of graphite. In the waste heaps of the Bittenbender iron mine one half mile northeast of Seisholtzville, a variety of rocks was observed. Some specimens were found composed of plagioclase, quartz, augite, and flakes of graphite one-eighth inch in diameter; others composed of massive hornblende, augite, hypersthene, and graphite; some composed of dark red garnet, hornblende, augite, and graphite. Still other specimens consisted of massive magnetite with occasional partings of graphite. In no other place in the state has such a variety of graphitic rocks been observed, so that it is especially unfortunate that the mine is no longer accessible and the relations of these various rocks remain unknown.

One mile south of Seisholtzville there is an iron ore prospect in a dark-colored banded gneiss composed of plagioclase, quartz, hornblende, biotite, magnetite, garnet, pyrite, and graphite.

Although the graphite of the basic gneisses is in the form of large flakes the basic gneisses seldom, if ever, carry sufficient graphite to make them desirable. Besides, the flakes are in most cases rather thick and consequently separated with difficulty from the associated minerals by the ordinary flotation processes.

Crystalline Limestone.—The limestone in which graphite is found is a coarsely crystalline calcareous rock that outcrops in many places in the state. The Second Pennsylvania Geological Survey called it "sparry limestone." Because of its purity it was formerly quarried in many places in Northampton, Bucks, and Chester counties and burned for lime. With the gradual decline of local limestone-burning for fertilizing purposes, these

quarries have been abandoned and at present the rock is not utilized.

In the Trenton folio of the United States Geological Survey Miss Bascom has designated this formation, "Franklin limestone," correlating it with the pre-Cambrian formation of that name that contains the valuable and unique zinc deposits of Franklin Furnace, New Jersey. On lithologic grounds there are good reasons for such a correlation since specimens from various localities in Pennsylvania could not be distinguished from similar materials quarried in the Franklin Furnace region. The geologic occurrence of the crystalline limestones of the Trenton region also seems to agree with that of the Franklin formation of New Jersey. There is, however, some doubt as to whether it should be regarded as a distinct formation. There is evidence that seems to indicate that it is merely a phase of the graphitic gneisses. The question will be further discussed in connection with the description of these gneisses on a later page.

This limestone is very coarse-grained. In certain places the individual particles are as much as an inch in diameter. Graphite, or graphite and phlogopite, in small thin flakes about one-eighth inch in diameter are rather evenly distributed throughout the rock with no apparent order of arrangement. This is especially noticeable where the limestone contains no other mineral impurities. In certain places, however, the crystalline limestone is decidedly impure, containing many basic silicate minerals arranged in approximately spherical segregations varying from a few inches to several feet in diameter. The graphite associated with such segregations is, in most cases, in much larger flakes. Some of the flakes are one-half inch in diameter, and many of them show distinct hexagonal outlines.

No bedding places can be observed in these rocks, consequently their structure and thickness are not determinable. Judging from their restricted outcrops, they are probably not more than a few hundred feet thick.

Although the graphite flakes of the crystalline limestones are fairly large, thin, and tough, they are of little economic impor-

tance as sources of graphite because of their low graphitic content. No attempts have been made to work them for graphite and probably never will be, although similar rocks were at one time worked near Ticonderoga, New York.

Acid Gneisses.—The most important graphite-bearing rocks of Pennsylvania are acid gneisses that are well developed in many places in Bucks, Lehigh, Berks, and Chester counties. All the successful graphite operations of the state have been confined to such rocks.

In mapping the crystalline rocks of the Trenton quadrangle Miss Bascom included the graphitic gneisses in the Baltimore gneiss but in her geologic map of the Phoenixville quadrangle, which will later be published as part of a folio by the United States Geological Survey, she proposes to separate the graphitic gneisses from the non-graphitic gneisses of the Baltimore formation. She has suggested the name "Pickering gneiss" for the graphitic gneisses and by that name they will be designated in this article.

The Pickering gneiss is a metamorphosed pre-Cambrian sediment that is composed primarily of feldspars, both orthoclase and plagioclase, quartz, biotite mica, hornblende, calcite, and much graphite. Less common constituents are pyrite, pyrrhotite, magnetite, and their alteration products, limonite, epidote, zoisite, chlorite, allanite, titanite, zircon, sillimanite, and garnet.

The rock is extremely variable both in mineralogical composition and in texture: some layers consist almost entirely of feldspar and quartz; some lenses observed in the underground workings of the Continental (Acme) mine are practically quartz schists; some layers or lenses contain much biotite and no graphite; some both graphite and biotite; while others show an absence of both these minerals. Certain layers carry so much calcite that the rock might be called a calcareous gneiss. The calcareous phases have not been observed at the surface but are well exhibited in the deeper parts of the Pennsylvania and Continental mines near Byers.

The basic silicates or iron minerals are almost always present and the soils of the Pickering gneiss are almost invariably stained

red by the limonite and hematite resulting from their decomposition. For this reason, the soils can be used in mapping even where no outcrops occur. In Pickering Valley several limonite mines were formerly worked in the graphite gneiss and the washings from these mines contain much graphite, as do also the limonite nodules. The miners early recognized the relation between the graphite-bearing beds and the iron-ore bodies. Observations seem to show greater amounts of pyrite and pyrrhotite in the beds containing most graphite, so it seems very probable that the graphite, or the carbonaceous matter that gave rise to the graphite, caused the original precipitation of the iron sulphides by the reducing action of the carbon. Later the iron sulphides formed the brown iron ore deposits through their decomposition by oxidation and the segregation of the oxidized products. In the open cuts of the Pennsylvania and of the Pettinos Brothers' mines at Byers the different stages in the process can be plainly seen.

The gneiss shows banding in most places, due to the parallel arrangement of the minerals, particularly the mica and graphite, and to partial segregations of the light and dark minerals in more or less distinct lavers. In a few places the rock is even schistose in appearance.

That the Pickering gneiss has undergone intense squeezing is shown by the complicated dips and strikes of the beds and by the numerous faults. Slickensided surfaces are encountered frequently in almost all the mines and it is not unusual to have the rich graphite-bearing layers faulted to such an extent that they cannot be followed. Faults both parallel to the beds and at almost right angles to them have been encountered in close proximity in the Pennsylvania Mine at Byers.

Dikes of igneous rocks have been encountered in several places in the Pickering gneiss. In the quarry of the American Flake Graphite Company a dike of basic rock varying from three to eight feet in thickness cuts across the beds vertically. It is so badly decomposed that it is difficult to determine the original character of the rock. A little graphite obtained from the beds

through which the dike was intruded was noticed in the outer portion but the interior of the dike is barren.

The graphite gneiss readily undergoes decomposition and in most mines in the state is so thoroughly decayed even at the lowest levels worked that the crushing of the rock is an item of small expense. There are exceptions to this, however.

The graphite of the Pickering gneiss occurs in three forms: (1) as an important constituent of the rock evenly disseminated in interlocking grains with the other rock minerals, (2) in pegmatites, and (3) in small veins.

1. The graphite, evenly disseminated throughout the rock, constitutes the bulk of the graphitic material of the Pickering gneiss and is the main source of supply. As stated above, some layers of the Pickering gneiss contain little or no graphite, while others contain so much mica accompanying the graphite that it is unprofitable to work them. An attempt was made to trace the workable beds of graphite throughout the Pickering Valley, but without much success. Some evidence has been obtained to indicate that the graphite bed worked by the Federal Graphite Company is a persistent bed that continues westward several miles and is the one worked in the Pettinos Brothers' mine, and the Pennsylvania mine, but the evidence is not conclusive. Certainly graphite flakes can be found in the soil all along a line drawn to connect those mines, but more exploratory work is necessary before it can be proved that the same bed extends so far. The Anselma mine seems to be sunk on a different bed, as do each of the other mines. It seems probable that rich and poor graphite-bearing beds in the form of more or less persistent lenses occur in many places throughout the Pickering gneiss.

The richer graphite-bearing beds are in some places sharply separated from the non-graphitic beds but more frequently one observes a gradual diminution in the amount of the graphite in the overlying and underlying strata. The thickness of the beds rich enough to warrant working varies greatly in the different mines. In some places the workable beds are only six to ten feet in thickness and two or more beds may be worked in the same

mine, while in other mines the total thickness of workable material in the bed has not been determined but it is more than one hundred feet. Naturally in the thicker beds there is somewhat more variation in the graphite content than in the thinner ones.

The amount of graphite contained in the Pickering gneiss varies so much that it is difficult to make any statement of the average percentage. One operator in the Pickering Valley district claims that the rock worked for graphite contains an average of about three per cent graphite; another maintains that the average is six per cent to seven per cent; while individual mine operators claim that the ore which they work contains an average of ten per cent. Picked specimens have been analyzed and have yielded even higher percentages. Because of the marked variation in amount and the limited number of analyses available it is only possible to make a comparatively rough estimate. It seems probable that the average graphite content of the rock varies from three per cent to five per cent of which about eighty per cent is recovered.

The graphite flakes of the Pickering gneiss seldom show hexagonal outlines such as those found in the limestone. They are thin, are arranged parallel to the bedding planes, and, in the main, vary in diameter from one-sixteenth to one-eighth inch, with the average probably about the mean of the two. In certain places the flakes are even larger than one-eighth inch in diameter and occasionally rather thick flakes are encountered. The thick flakes are less desirable because of the difficulty of recovering them by the flotation processes of concentration. The physical texture of the flakes also varies. In some places the individual particles of the flakes are so loosely bound together that in milling they are apt to be ground to a powder, while others are harder and firmer and can be cleaned much more effectively.

2. The second method of occurrence of the graphite of the Pickering gneiss is in the pegmatites that are abundant in almost every locality. In no mine have the pegmatites been worked exclusively as the source of the graphite. On the other hand,

there are few mines where the pegmatites have not yielded a considerable amount of the mineral.

The pegmatites vary in width from a few inches to fifteen feet or more and have a considerably greater length. They are mainly enclosed between beds of the gneiss, having the same dip and strike as the adjoining strata. However, it is not at all unusual to find the pegmatites cutting across the gneiss beds.

The pegmatites of the Pickering gneiss are so coarse-grained that they are readily distinguished from the enclosing layers of gneiss. They consist almost entirely of gray orthoclase and quartz in grains varying from one-fourth inch to one inch in diameter. The graphite present is also in large thick flakes, many of which are one inch or even more in diameter. In some of the pegmatites the graphite is found evenly distributed throughout the feldspar and quartz with the flakes oriented in all directions, but in others the graphite occurs in bunches of curved flakes. Many of the pegmatites contain graphite only in the outer portions while the interior is entirely devoid of it. This seems to indicate the surrounding rocks as the source of the graphite. The pegmatites were doubtless formed at the time that the region was squeezed, folded, and faulted, and the carbonaceous matter of the original rocks converted into graphite. If that is the case, the aqueo-igneous matter which formed the quartz and feldspars of the pegmatites picked up the carbonaceous matter of the rocks through which it passed, and, under the action of great heat and much aqueous vapor, caused the carbon to crystallize in large flakes in the outer portions of the mass. Where the graphite occurs throughout the entire pegmatite body and shows no regular arrangement of the flakes it seems probable that the carbon in some form, perhaps as CO or CO_2, was an original constituent of the mass, as were the materials that gave rise to the quartz and feldspars.

Although the richest specimens of graphite can be obtained from the pegmatites, these bodies are of comparatively little economic importance. The average percentage of graphite is probably slightly less than in the surrounding rock and the

graphite is of poorer quality. Bunches of practically pure graphite an inch or more in thickness may be obtained but the material is so friable that in the milling it is practically reduced to a powder and either lost or else recovered in the form of dust, the least valuable product. Also some of the thicker pieces are heavy enough to sink with the quartz and feldspars and pass into the tailings.

3. The third way in which graphite occurs in the Pickering gneiss is in the form of veins. These are not common although they have been observed in the old dumps of the abandoned mine near Trevose and in several of the mines near Chester Springs and Byers. No veins of greater thickness than three-fourths inch have been observed, although larger ones have been reported to occur.

The graphite in the veins is practically pure but less lustrous than that occurring as disseminated particles through the gneiss. It occurs in the foliated form with the plates or leaves projecting outward at approximately right angles to the walls of the enclosing rock. The leaves are somewhat curved and resemble closely the Ceylon graphite. They were doubtless formed in the same way. These veins are so infrequent that they are of little economic importance in the graphite region of this state.

RELATIONS OF THE CRYSTALLINE LIMESTONES AND THE GRAPHITIC GNEISSES.

In the above discussion the Franklin Limestone and Pickering Gneiss have been treated as separate formations and it is probably advisable to map them as such because of their different economic uses. Also in many places there seems to be a sharp line of separation between them. In other places, however, it is not possible to draw a sharp line and we have calcareous graphitic gneisses that might with equal reason be placed in either formation. We seem to have a duplication of the Grenville series of the Adirondack region where limestones, gneisses, schists, and quartzites occur in almost inextricable relationships. The workable graphite deposits of New York are contained in the Gren-

ville rocks, mainly in the quartzites. These rocks are believed to represent the metamorphic products of calcareous or siliceous shales. A similar explanation seems satisfactorily to explain the Franklin limestone and Pickering gneiss of Pennsylvania.

According to the above view, the two formations were formed originally as contemporaneous sediments that varied in different places. In some localities fairly pure limestone was being deposited while in adjacent regions were accumulating calcareous muds or siliceous muds in which there was little or no calcareous material. When these sediments were later metamorphosed the beds composed mainly of calcareous matter formed the rocks called the Franklin limestone; the calcareous muds gave rise to the calcareous graphitic gneisses observed in the underground workings of the Pennsylvania and Continental (Acme) mines; the muds with little calcareous matter formed the bulk of the Pickering gneiss; and the more siliceous sediments formed the quartz schists such as occur in the lower levels of the Continental (Acme) mine and which contain only very small amounts of graphite. The quartz schist or quartzite phase is not well represented in Pennsylvania, while in New York it forms perhaps the most important member of the Grenville series from an economic standpoint.

On the surface the relations described above are not readily apparent because of the solution by percolating waters of the greater part of the calcareous matter in the originally calcareous graphitic gneiss. We thus have outcropping only the two kinds of materials, the relatively pure crystalline limestone and the decomposed graphitic gneiss, consequently the line of separation between them seems to be rather sharp. Underground, however, where solution has been less effective, the two grade into each other through the calcareous gneiss.

Although bedding planes are not apparent in the Franklin limestone, it seems probable that the limestone and gneiss are conformable. This conclusion is based on the fact that the limestone occurs in lenticular masses with the greatest length parallel to the strike of the gneiss beds in some localities. If it were

possible to obtain the necessary data, it would probably be found that such relations exist in other places as well. If, then, we can prove that the two formations are conformable, with the Franklin limestone intercalated within the Pickering gneiss, we have sufficient evidence for the view expressed above that the two are of contemporaneous origin and represent merely different lithologic phases of the same series of sediments.

ORIGIN OF PENNSYLVANIA GRAPHITE.

The graphite of Pennsylvania is believed to be of organic origin, with the possible exception of that found evenly disseminated throughout the pegmatites or that occurring in veins, and the rocks in which the graphite occurs are believed to be altered sediments. Certainly all evidence at hand seems to indicate that the graphite disseminated throughout the limestones and gneisses in the form of flakes has been derived from the carbonaceous remains of plants or animals, probably chiefly of the former. Also in the case of those pegmatites in which the graphite occurs near the peripheries it seems probable that the carbonaceous material was derived from the adjacent sediments. The vein graphite and also the graphite evenly distributed throughout the pegmatites may, however, be of inorganic origin.

The sediments that have given rise to the Franklin limestone and Pickering gneiss were probably shallow-water marine deposits, as is indicated by the variation in lithological composition. Such conditions would furnish favorable places for the growth of marine plants whose remains would be enclosed in the strata. Later, when earth adjustments took place and the strata were squeezed and folded, the resulting pressure and heat probably converted the amorphous carbon into crystalline graphite.

Regional or dynamic metamorphism has been the main cause of the formation of the Pennsylvania graphites, but the effect of contact metamorphism is also apparent. The numerous pegmatite dikes that have been injected into the gneisses to such an extent that in many places they are properly called "injection gneisses" have also been effective, as is proved by the presence

of larger flakes of graphite in their immediate vicinity than elsewhere in the gneiss.

SUMMARY.

Graphite occurs in many places in the Piedmont Plateau crystalline rocks of southeastern Pennsylvania and has been mined in Chester, Berks, Lehigh, and Bucks counties. The earliest known operations date back to about the middle of the eighteenth century, but little mining seems to have been done prior to 1870. From 1895 to 1907 the graphite industry attained its maximum development, although some mines have been operated each year since 1907.

The rocks carrying graphite arranged in increasing order of importance consist of sandstones, gabbros, limonite iron ores, basic gneisses, crystalline limestones, and acid gneisses. Up to the present time the only successful mines have been worked in the acid gneisses. These graphitic gneisses are known as the Pickering gneiss. The graphite occurs in them in three forms: (1) as an important mineral constituent of the rock, (2) in pegmatites, and (3) in small veins. Most of the commercial graphite is obtained from rocks in which it is present in the first mentioned form.

The Pennsylvania graphite deposits have originated through the regional metamorphism of shallow-water marine sediments, although there is evidence to show that contact metamorphism has also been effective.

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DISCUSSION

This department has been established by the editors in order to afford to those interested in questions relating to economic geology an opportunity for informal discussion. Contributions are cordially invited either in the form of discussion of more formal papers appearing in earlier numbers or bearing upon matters not previously treated. Letters should be directed to the Editor, Sheffield Scientific School of Yale University, New Haven, Conn. The full name of the author should be attached to all communications.

THE PLANE-TABLE IN GEOLOGIC MAPPING.

A LIGHT PLANE-TABLE EQUIPMENT FOR USE IN GEOLOGIC AND TOPOGRAPHIC MAPPING.

Sir: In the February–March number of ECONOMIC GEOLOGY[1] Mr. F. L. Ransome discussed the use of the plane-table in precise geologic mapping on an accurate topographic base. He expressed the hope that his initial paper would call forth a discussion of the use of the plane-table in geologic mapping under other conditions.

In the course of mapping several small areas of complex geology and extremely rugged topography, equipment, and methods of procedure differing somewhat from those described in Mr. Ransome's paper were used. In the hope that a description of this simple and inexpensive equipment may prove of value to others engaged in work of a similar nature, the following notes are offered.

Conditions necessitated the use of large scale maps—200 and 400 feet to the inch. In general the topography of an area should be mapped before the geology, but in certain areas of precipitous topography and simpler geology it was considered advisable to do the topographic and geologic work simultaneously.

Instruments.—Because of an extremely rugged country, the

[1] "The Plane-Table in Detailed Geologic Mapping," by F. L. Ransome, ECONOMIC GEOLOGY, Vol. VII., No. 2, pp. 115–119.

equipment was selected to meet the requirements of simplicity and lightness, and consisted of the following: a light plane-table, Graton alidade, hand stadia, Brunton compasses, and accessories.

Table.—The table, 15 in. × 18 in., is of ½ in. soft pine, cleated at both ends to prevent warping. A ⅛ in. circular brass plate 3 in. in diameter, and provided with a threaded hole to receive the tripod screw, is set in flush with the bottom of the table to which it is attached by countersunk screws. The table is mounted on an Eastman No. 4 combination tripod.

At adjacent corners two carpenters' level bubbles are set in the edges of the table with plaster of Paris to provide a simple means of levelling. A small wooden box containing the drawing instruments is pivoted by a screw through one end to the under side of the table, thus allowing it to swing out so that its contents are readily accessible, a spring wire being used to hold the box in place when closed. For convenience a strip of emery cloth for pointing pencils is thumbtacked to one edge of the table. As orientation is accomplished by a delicate compass needle, care should be taken to avoid the use of any magnetic material in the construction of table or tripod.

Map.—The map is plotted on linen-mounted buff drawing paper. If white paper only is obtainable, an excellent substitute is made by tinting this with a thin wash of brown ink to avoid excessive glare from the sun. On this map the coördinates, claim lines and posts, workings, triangulation stations, and in fact any objects already accurately located are plotted. A light line indicating the magnetic north for the current year is drawn the full length of the map.

Alidade.—The alidade used is a Graton Improved Alidade (Bausch and Lomb, manufacturers) consisting of a 7½ in. straight edge fitted with open compass sights. A very delicate needle in a compass box is mounted on the straight edge midway between the sights. These sights fold down and the whole instrument fits in a small leather case which may be carried on the belt.

Stadia and Rod.—A most useful adjunct to the plane-table equipment is a hand stadia with ball and socket levelling attachment and slow motion screw mounted on a separate camera tripod. Placed in a leather sling case the stadia may be carried safely in the roughest country.

A 6-foot folding rule graduated in feet and tenths is used as a stadia rod. Targets of the usual pattern made from linen backed drawing paper are used. The upper target is attached to the rod by paper clips; the bottom target is merely moved up or down in front of the rod. Readings are communicated orally, though signals may be used when the distance is too great.

Accessories.—For reducing slope distances to their horizontal and vertical components, either a stadia slide rule or a simple form of conversion table thumb tacked to one corner of the table may be employed.

Method of Procedure.—Before beginning the actual work of plane-tabling, triangulation flags must be put on prominent points and their position and elevation determined. If no points are already accurately located and the work is such that the use of a transit for establishing several control points is not warranted, a base line must be run, a station established at each end, and from these a series of points shot in by resection, using the alidade as in ordinary triangulation work of this nature. Greater speed and accuracy in the subsequent mapping will be obtained by establishing these points at frequent intervals. This work also serves to familiarize the operators with the general geologic and topographic features of the area.

Locating.—The table is set up on some commanding point and its location determined by the three point method as described in Mr. Ransome's paper. Trouble will arise where the position of the table is at or near the center of the circle determined by the three points sighted. In this case the problem is indeterminate, and one of the points must be discarded for a new one not on the circle.

If the table is not oriented correctly, the lines of sight will not

meet in a point but will form a triangle of error. In this case the solution recommended by Ransome or the following will be found applicable: a second triangle of error is obtained by turning the table a few degrees in either direction, the same three points again being sighted. Lines drawn through similar vertices of the two triangles will meet in a point which is the correct location of the table.[1]

Determination of Elevation.—Where the elevation of a set-up is necessary, the vertical angle is read from a Brunton compass laid along the top of the stadia which has been sighted at some point of known elevation. The horizontal distance to this point is scaled from the map, and with this data the difference in elevation may be determined. A more accurate method where the vertical angle between the set-up and the point of known elevation is less than 6 degrees is as follows: one of the stadia wires is turned on the point, and the stadia then leveled, observing by coincidence of the other wire on any object such as a rock or bush the number of intercepts made before the bubble is brought to level. The number of intercepts multiplied by the stadia ratio (1:100) times the horizontal distance to the point gives the difference in elevation.

Under fair working conditions the table may be set up and its location and elevation determined in 4 to 5 minutes.

Locating Details.—The station being determined, the location of details is carried on by the ordinary methods of plane-tabling.

A celluloid protractor-triangle graduated to degrees is used in plotting. This, with notebook, pencils, eraser, and scale completes the table equipment. The annoying loss of pocket lens and eraser may be avoided by fastening these articles to a button-hole by a string of suitable length.

The rodman carries a Brunton compass, notebook for detail sketching, stadia rod and geologic pick.

In topographic work where the slopes are regular, much time may be saved and additional accuracy gained by the rodman tak-

[1] A full explanation of this solution may be found in Hayes' "Handbook for Field Geologists."

ing slope angles with their bearings and also the bearing of the contours. With this information and the conversion table the operator may locate one or two contours above and below the point occupied by the rodman. To facilitate the work the following form of notes was used by the tableman, the horizontal and vertical distances being filled in from the conversion table. This permits of plotting while the rodman is gathering additional geologic data at another point. The opposite page is reserved for computations, sketches, etc.

Slope Distance.	Hor. Dist.	Vert. Angle.	Vert. Dist.	Elev.	Notes.
At Sta. 25				5,700	
175	154	+28°	+82	782	Ridge runs N. 45° W.
145	129	−27°	−66	634	Vein S. 45° W. N. W. 65°.

Specimens.—A record of specimens is kept in the notebook giving index number, location by coördinates, field name and purpose for which the specimen is taken. For reference to the specimens a separate map is made on tracing linen. This map consists merely of coördinates and the location with index number of each specimen, and may be placed over the geologic map for comparison.

Geologic Map.—A tracing is made directly from the field map, and from this white prints are taken. The classes of rocks, veins, etc., are indicated by symbols and tinting, following the custom of the U. S. Survey.

Accuracy.—Working on a 200-scale map, locations may be made as close as it is possible to plot.

Weight of Equipment.—

Tripod (for table)	3½ lbs.
Table	3½ "
Compass, tape, stadia rod, and alidade	2½ "
Stadia and tripod	3 "
Total	12½ "

Approximate cost of equipment.—

Graton alidade	$18.00
Hand stadia	18.00
Ball and socket and levelling attachment	4.50
Stadia rod (6-foot folding rule)	.60
Tape, drawing materials, etc.	3.50
Tripod for table and stadia	6.00
Plane table	3.50
Total	$54.10

E. F. PELTON,
D. D. IRWIN.

A PECULIAR OCCURRENCE OF SILVER.

Metallurgists who employ the cyanide process for the extraction of silver from its ores have found a match for their skill in an uncommon kind known as refractory manganese-silver ore. Here there is an association of the silver with the manganese that has received little attention from mineralogists and data are presented in the hope that some of those interested in ECONOMIC GEOLOGY may be able to offer suggestions as to the nature of the mineral. The cyanide process fails absolutely on this ore. The failure is not due to salts which decompose cyanide or cause premature precipitation as in the case of other refractory ores, but to the insolubility of the mineral. The mineral is also insoluble in nitric acid. The occurrence of a silver mineral that is insoluble in both potassium cyanide and nitric acid was not recognized until a little more than two years ago. Large quantities of these ores occur in Mexico; one such deposit has been found in the United States, and there is evidence of many more.

These ores are always thoroughly oxidized and contain manganese dioxide. Samples from the mines are always so stained with dioxide that it is impossible to identify any of the mineral constituents without a preliminary wash in some dilute reducing agent which will dissolve the dioxide stain. After such a treatment, hand sorting is a simple matter. Metallurgists were

of the opinion for some time that the silver was uniformly distributed through the dioxide, but it was proved by sorting and assaying the assorted products that this was not the case; the pure pieces of dioxide contain very little silver, but there is a zone along the contact between the gangue and the dioxide, where the dioxide acts as cementing material toward the particles of gangue minerals, that assays very high in silver. Microscopic investigation of slides showing this contact reveals dark brown blotches which do not appear in any other portion of the dioxide. Since they occur in what was proved by sorting and assaying to be the zone of enrichment, it seems more than likely that they constitute the refractory silver mineral. The annexed micro-section (Fig. 93) shows one of several slides

FIG. 93.

that were examined. All of these slides show the same structure.

An interesting property of the mineral is that the silver is amenable to amalgamation and dissolves very readily in the ordinary solvents of silver after the dioxide has been dissolved; it shows very much the same chemical deportment as does precipitated silver, indicating that any acid such as sulphurous acid

which dissolves the dioxide also decomposes the silver mineral and precipitates metallic silver. It amalgamates and dissolves in cyanide much more rapidly than native silver. Physical as well as chemical tests indicate that it is in a condition not met in other ores, as shown by the following. After treating the powdered ore in sulphurous acid to dissolve the dioxide the gangue settled quickly leaving a slime which appeared to be mainly limonite and remained in suspension with great persistency. Upon decantation it was found that this slime assayed 380 oz. while the sand assayed only 10 oz. Ag. per ton. The number of mills treating sand and slime separately runs up into the hundreds and in no case is there such a segregation of silver in either sand or slime.

Here is a problem in both mineralogy and ore deposits as well as metallurgy.

The following constitutes a complete bibliography on this subject:

Mining and Scientific Press, Dec. 4, 1909, p. 756, by E. M. Hamilton.
Mining and Scientific Press, May 25, 1912, p. 732, by Byron Jackson.
Mining and Scientific Press, June 1, 1912, p. 754; June 8, 1912, p. 794, by Will H. Coghill.

WILL H. COGHILL.

NOTE ON THE EFFECT OF CALCITE GANGUE ON THE SECONDARY ENRICHMENT OF COPPER VEINS.

Some time ago Professor D. C. Bard called attention to the fact that copper veins with a calcite gangue usually show no secondary enrichment.[1] The calcite seems to react with the sulphate solutions formed in the oxidized zone, precipitating copper carbonate almost immediately, and thus preventing a downward migration of the metal. In an effort to verify this we have conducted some experiments in the economic geology laboratory of Cornell University, the results of which are given here.

Mixtures of chalcopyrite and quartz, and of chalcopyrite and

[1] ECON. GEOL., Vol. V., pp. 59–61, 1910.

calcite were made of fragments averaging one eighth of an inch in diameter. There were equal parts of ore and gangue minerals in each case. These mixtures were put into two-inch glass tubes, four feet long, set up vertically, and so arranged that solutions dropped continuously into the mixtures at the top, would trickle over the mineral fragments and drain out at the bottom of the tubes. This drainage was so conducted that a permanent water-level was maintained about a foot above the bottom of the tube, while the solutions were introduced slowly enough to keep barely moist the minerals above the water level. In one experiment a mixture of chalcopyrite and calcite and one of chalcopyrite and quartz were treated with a weak solution of copper sulphate. In the second experiment similar mixtures were treated with ordinary tap water. This was continued for three months, care being taken that the amounts of copper sulphate running through each tube were equal, and that the sulphate was fed in at the same rate. The following results were noted.

In the calcite-chalcopyrite mixture, treated with copper sulphate, the calcite above the water level was distinctly tinged with green, while none of the chalcopyrite showed any change. In the tube containing quartz and chalcopyrite no change above the water level was noted, but the chalcopyrite for four inches below this level showed clearly the purple tinge of bornite and upon closer examination some thin black films were found. No change was noted in the tubes treated with water, the time of the experiment evidently being too short to allow appreciable solution of the copper.

Unfortunately the chalcopyrite was not entirely free from inclusions of gangue, and in view of the large size of the fragments we could not be sure that samples taken from the tubes represented the same original copper content. The change in appearance in the chalcopyrite in the quartz gangue, however, was unmistakable, and there can be no doubt that at the water level a secondary precipitation of copper sulphide took place. It is equally certain that a similar action did not take place in the tube with the calcite gangue. Analysis showed that the cal-

cite used was free from copper, while after the experiment that above the water level showed .072 per cent. There was no increase in the SO_2 content of the calcite after the experiment, which seems to show that the $CaSO_4$ formed by the $CuSO_4$ and $CaCO_3$ was kept in solution. This is in accord with the fact that oxidized copper ores in calcite gangue commonly show comparatively little gypsum.

These experiments, although far from final, seem to establish the fact that calcite has a tendency to prevent the precipitation of secondary copper sulphide in conditions analogous to those prevailing in mineral veins. It seems probable, however, that this effect is not the result of the immediate precipitation of copper in the upper part of the vein as a carbonate. We found that the solution draining from the tube with the calcite-chalcopyrite mixture still showed considerable copper sulphate, and the cause of the non-precipitation of secondary sulphide cannot have been the removal of Cu as carbonate in the upper part of the tube. Winchell has shown that secondary chalcocite is most likely to be formed in acid solutions.[1] The ordinary copper sulphate is acid, and the effect of the calcite gangue may be to neutralize this acidity, and thus make conditions unfavorable for secondary enrichment. Further experiments should be conducted with analyses of the copper sulphate solution used and that draining from the tubes to establish this point.

T. W. B. Welsh,
C. A. Stewart.

REVIEWS

Dana's Manual of Mineralogy. By William E. Ford. John Wiley & Sons, New York, 1912, 13th ed., 460 pp., 357 figs., 10 pl.

The series of the Dana Mineralogies is without an equal and it is very gratifying that the "Manual" of James Dwight Dana (first published in 1848) has now been revised, rewritten, and made available for the student of elementary mineralogy, the mining engineer, the geologist, and the practical man interested in the subject. The book retains the character of the earlier editions, except that the chapter on Petrography has been omitted and the rock descriptions have been condensed. The text and illustrations are however nearly all new, as is made necessary by the great strides which the science of mineralogy has made in the last decades. Professor Ford has been very successful in keeping the scope of the old book while modernizing the text.

Crystallography is the first of the five divisions and the necessary elements of it are well treated. The second division describes the General Physical Properties of Minerals. Inasmuch as the character of the book is elementary, the author has been wise in the brief treatment he has given to certain topics, as for instance those depending upon light. The chapter on Chemical Mineralogy presents the chemical groups into which minerals are classified, treats of isomorphism, describes blowpipe determinations with short tables of the common tests, and gives a list of the simple tests for the common elements.

In the Descriptive Mineralogy, the text is attractively arranged under such headings as: Composition, Crystallization, Structure, Physical Properties, Varieties, Tests, Occurrence, Name, and Use, while for such minerals as demand it, additional paragraphs are introduced, as for example a paragraph on the gem qualities, cutting, and value of the diamond, and one on artificial graphite. The descriptions of the rarer minerals are grouped in one paragraph. Many very rare minerals are briefly mentioned. The commercially important minerals are grouped according to their useful chemical elements, followed by a discussion of their occurrence, the process of extraction of the element, and its uses. Statistics of production in the United States are given in an Appendix. The Occurrence and Association of Minerals is interestingly treated in sections entitled: Rocks and Rock-making Minerals, Pegmatite Dikes and Veins,

Contact Metamorphic Minerals, Veins and Vein Minerals. A list of minerals arranged after their system of crystallization closes this division.

The fifth and last division, that of Determinative Mineralogy, embraces the common species and the rare ones of economic importance. The tables given for their identification are based on physical properties but, as stated, reference should also be made to earlier parts of the book in order to include the chemical and other properties.

W. T. SCHALLER.

Mineralogy. An Introduction to the Theoretical and Practical Study of Minerals. BY ALEXANDER HAMILTON PHILLIPS. The Macmillan Company, New York, 1912. $3.75 net. 699 pp., 534 figs.

The facts and basic principles of the several branches of mineralogy are brought together for the beginner under the three heads of Crystallography, Descriptive Mineralogy, and Determinative Mineralogy. The descriptions are given with such fullness that a beginner may have trouble in digesting all, especially the descriptions of the thirty-two classes of crystals with their many and long names. Indices and similar notations are printed in heavy-face type instead of the usual italics. The Optical Properties are given in detail under Crystallography. The Descriptive Mineralogy of Part II. is introduced by two chapters, the first one on "The Relation of Minerals to the Elements" dealing with polymorphism, occurrence of the elements, water in minerals, isomorphism, classification of minerals. The second chapter, on "The Origin of Minerals", includes the various phases of substances, fusion with the different attendant phenomena, mineralizers, pneumatolysis, thermal metamorphism, hot solutions, and the action of ground waters. Before the description of minerals is undertaken, the physical properties (except those dependent on light which have been given under Crystallography) are defined and illustrated. The descriptions of minerals are concentrated in a short paragraph, giving name, composition, crystallography, general physical properties, followed by one on the blowpipe reactions. The various properties, occurrence, etc., are then grouped in several paragraphs under the heading "General Description". About two hundred and twenty-five species, including the common rock-forming and ore minerals, are thus treated.

Part III., on "Determinative Mineralogy", includes a description of the instruments, reagents, and chemical tests used in blowpiping. The more common minerals are grouped in two tables: I., metallic or submetallic luster, and II., non-metallic luster. Color is used as a further subdivision and the minerals are then arranged according to hardness. A table for the determination of the principal rock-forming minerals in

sections includes a little more than fifty minerals. A determinative table, based on blowpipe tests, extends for sixty-six pages and includes nearly all known species.

The book is richly illustrated. A large number of the illustrations are photographic reproductions of minerals, either as specimens or as isolated crystals. The work is an excellent text-book on mineralogy, though it contains much more information than a beginner would ever be called on to know.

W. T. SCHALLER.

Popular Guide to Minerals. BY L. P. GRATACAP. D. Van Nostrand Company, New York, 1912. 330 pp., 400 text figures, 74 plates, map showing distribution of minerals in the U. S.

The sub-title, "With chapters on the Bement Collection of Minerals in the American Museum of Natural History, and the Development of Mineralogy, for use of visitors to public cabinets of minerals and for elementary teaching in Mineralogy," gives a good idea of the book's scope. The first sentence of the preface reads: "This guide is intended for use by visitors to collections of minerals," though a book weighing nearly three pounds and with no index to the illustrations may prove somewhat burdensome to the museum visitors. The photographic reproductions are excellent and give one a good idea of what the minerals look like. They are scattered promiscuously through the book with no reference or relation to the text. A beautiful photograph of velvety malachite is bound in with the text on garnet; a fine one of stalactite azurite with the text on the micas, etc.

The following paragraph on silver (page 112) illustrates the mode of treatment of mineral occurrences.

"The extraordinary wedges or 'leads' of native silver in the Cobalt, Ontario, region of Canada are difficult to account for. Silver is reduced from its sulphide and antimonide and it is also precipitated from its solution by pyrite, chalcopyrite, galena, and other sulphides. Reactions, perhaps similar to these, accumulated in beds (afterwards inverted), these silver masses."

The book may well serve to induce in the general reader an appreciation of the beauties of minerals so admirably set forth in the large number of illustrations.

W. T. SCHALLER.

SCIENTIFIC NOTES AND NEWS[1]

ANNOUNCEMENT WAS MADE on November 15, 1912, of changes in the organization of the geologic branch of the U. S. Geological Survey. These changes seem to have been instituted through the resignation of Mr. Waldemar Lindgren, who goes to the Massachusetts Institute of Technology to assume charge of the department of geology. He is succeeded in the Survey by Mr. David White, who became chief geologist on November 16.

The following other changes have been made in the official staff. To quote from the circular issued by the Director of the Survey:

"The chief geologist will be in charge only of the division of geology and paleontology, and the other divisions will report directly to the director. This change may be regarded only as temporary, and for the purpose of reducing the administrative burden placed upon the successor to Mr. Lindgren.

"Mr. Ransome will succeed Mr. Lindgren as geologist in charge of the section of economic geology, metalliferous deposits, with Mr. J. B. Umpleby as assistant to chief of section.

"Mr. McCaskey will succeed Mr. Lindgren as chief of the metalliferous section of the division of mineral resources, exercising general supervision over the collection of statistics of metalliferous production and the preparation of chapters on those subjects.

"The western offices of this division will continue to be under the direct administration of Mr. McCaskey. In the coördination of the geologic and statistical work on metalliferous deposits Messrs. Ransome and McCaskey will necessarily coöperate.

[1] Geologists, mining engineers and others interested in applied geology are invited to keep the editor informed of new investigations of mining districts or scientific studies undertaken by them, together with such other scientific and personal items as may come to their notice.

"With the growth of the scientific work of the Survey, it appears advisable to distribute its administration more widely than was necessary in the past, and to place rather more than less administrative responsibility upon the geologists of experience. To this end the effort will be continued to give the individual geologist a large degree of independence, and at the same time insure the coördination of the extensive and varied research work of the branch. Strong control by the geologists selected to serve as section chiefs is essential if uniformity of standards of work is to be secured as well as freedom from duplication and interference in the case of closely related investigations. Yet if these chiefs are to be spared for the scientific work in which they are leaders, the constant effort must be made to relieve them from the petty though necessary details of administration by sharing the burden."

PROFESSOR HARRY FIELDING REID, of Johns Hopkins University, delivered a lecture before the Geological Section of the New York Academy of Sciences on December 2. His subject was "The Seismograph and What It Teaches."

ON NOVEMBER 13, Mr. David White read before the Geological Society of Washington a paper entitled "The Work of the Conservation Congress." On November 27 the following papers were read before the same Society: "The Joplin Lead and Zinc Deposits," by C. E. Siebenthal; "Secondary Sulphide Enrichment in Silver," by E. S. Bastin; "The Quality of the Water obtained by Leaching Feldspar, a Critique," by Chase Palmer.

THE SIXTY-FOURTH meeting of the American Association for the Advancement of Science will be held at Cleveland, Ohio, from December 30, 1912 to January 4, 1913.

MR. J. B. TYRRELL, of Toronto, Canada, who returned recently from an extended expedition into the Hudson Bay region, sailed on November 30 for a short visit to England. His English address is 224 Salisbury House, London, E. C.

THE AMERICAN PEAT SOCIETY held a meeting on September 5, 6, and 7, at Columbia University, New York City, in conjunction with the International Congress of Chemists. Papers were read by J. A. Holmes, J. H. Pratt, W. R. Beattie, T. Arthur Mighill, and others.

THE FOLLOWING are the delegates appointed by President Taft to the convention of the American Mining Congress held at Spokane, Washington, November 25 to 29: H. Foster Bain, San Francisco; Philip N. Moore, St. Louis; H. L. Hollis, Chicago; D. W. Brunton, Denver; Erskine Ramsay, Birmingham; James W. Malcolm, Kansas City; C. W. Goodale, Great Falls, Montana; E. H. Benjamin, Oakland, California; J. A. Holmes, Washington; and Stanley J. Easton, Kellogg, Idaho.

DR. FRED. E. WRIGHT, of the Geophysical Laboratory of the Carnegie Institution of Washington, will give a course of lectures on experimental geology at Johns Hopkins University beginning in January, 1913. The results which have already been secured in experimental geology will be reviewed and attention directed to those geological problems which are still unsolved and in which experiment may render efficient aid. Dr. Arthur L. Day, director of the geophysical laboratory, will coöperate with Dr. Wright in some of these lectures.

THE SECOND SEASON of the field school of geology of the University of Chicago was spent in the San Juan Mountains of southwestern Colorado. The party prepared an areal geological map of about two hundred and fifty square miles. This work was done under the direction of Dr. W. W. Atwood and in conformity as far as possible with the official methods of the United States Geological Survey.

MR. RALPH ARNOLD, of Los Angeles, spent the first half of November in Trinidad investigating the property of the Barber Asphalt Company.

G. A. WARING, who has been employed by the government of Brazil for the past two years, reports that his investigation of

the water supply of the plateaus in northeast Brazil is well advanced and that he expects to return to the United States at the expiration of his contract in July, 1913.

J. M. HILL, of the U. S. Geological Survey, went into the Navajo Indian Reservation during the past summer to examine certain copper claims for the purpose of classifying the land as mineral or non-mineral.

MAX W. BALL left Washington recently for Utah to join C. T. Lupton in the San Rafael swell region, where the U. S. Geological Survey is making a reconnaissance examination of certain reported structures favorable for the accumulation of oil.

R. W. RICHARDS has completed a geologic survey of the Melrose, Montana, phosphate field for the Federal Survey.

S. R. CAPPS has returned to Washington after making a detailed investigation of the geology around Ellamar and Land Locked Bay, Prince William Sound, Alaska.

N. H. DARTON, of the U. S. Geological Survey, lectured on November 22 to the New York section of the American Institute of Mining Engineers. He described the structure of the northern anthracite coal basin of which he has recently completed a very detailed map showing the deformation by 100-foot contours. Sections were presented which exhibited notable differences between structure revealed by mining and that indicated by surface dips.

IN THE THIRTY-THIRD ANNUAL REPORT of the Director of the United States Geological Survey, the director urges upon Congress the construction of a special building for the housing of the Geological Survey in Washington. To those who are familiar with the building on F Street, in which the work of the Survey has been done since 1884, the plea made by the director for suitable accommodations will appeal as not only an absolutely essential thing, but something which it is difficult to believe has

not been long since provided. The incredibly difficult and unsatisfactory conditions under which the valuable and extensive work of the Geological Survey has been conducted, and the danger which has been constantly felt of the destruction of valuable records by fire make the delay in supplying suitable quarters the more difficult to understand. It is the earnest hope of all the wellwishers of the Survey that they may succeed in a very short time in securing what the admirable work of the office of the Survey staff has for many years thoroughly merited.

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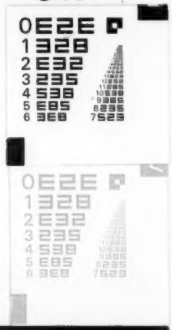
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